JUL -3 1961
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ELECTROMECHANICAL

components & systems DESIGN

JULY 1961

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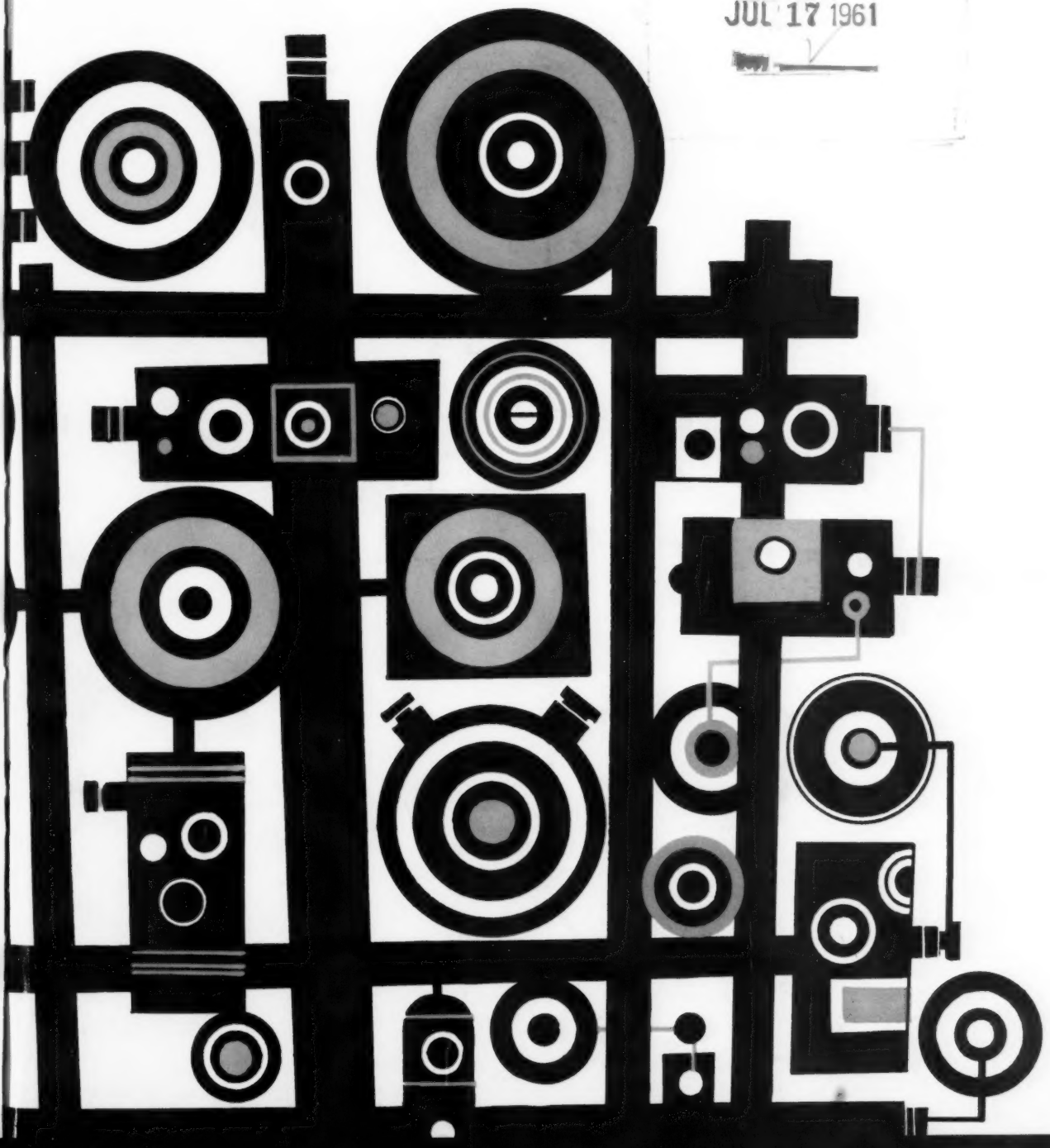

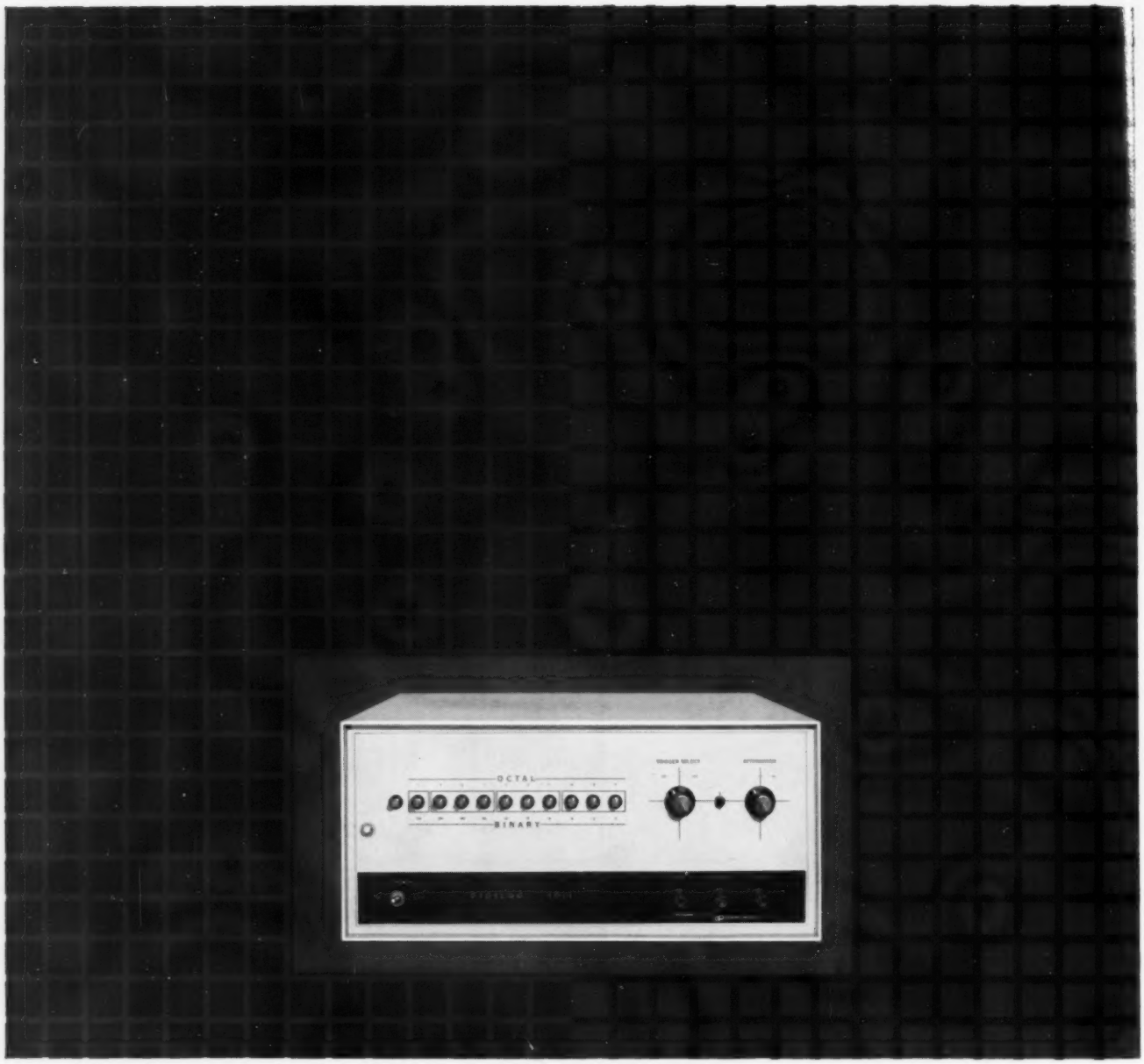

INTRODUCING LIBRASCOPE'S ELECTRONIC DIGILOG*-1011 FOR VOLTAGE-TO-DIGITAL/DIGITAL-TO-VOLTAGE CONVERSIONS

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*TRADEMARK, GENERAL PRECISION, INC.

GENERAL PRECISION

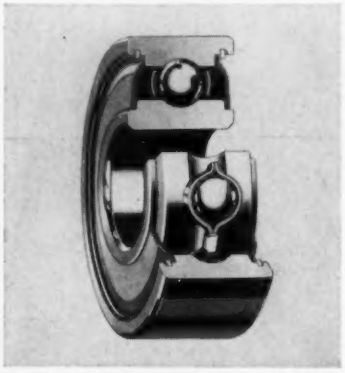
LIBRASCOPE DIVISION | GENERAL PRECISION INC., GLENDALE 1, CALIFORNIA

CIRCLE NO. 1 ON INQUIRY CARD

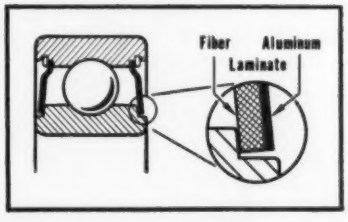
A NEW PRODUCT DEVELOPMENT FROM BARDEN

TO KEEP YOUR BRAINCHILD SPANKING CLEAN

A spaceman's helmet can keep a boy's face clean for a while, but the protection is far from permanent. A new Barden development, however—Flexeal—positively seals precision bearings against dirt while retaining needed lubricant, thus greatly increasing the reliability of high-speed motors, generators, computer memory drums and other equipment.



Sectional views of Flexeal precision bearing show how fiber-aluminum laminate seals against ground surface of inner ring to effectively block out dirt and retain bearing lubricant.



SEALED PRECISION BEARINGS

Barden's new Flexeal meets the demand for a low-friction seal that can stand up at high speeds in contaminated environments. Flexeal bearings are precision bearings with a seal of fiber-aluminum laminate that fits smoothly against a ground surface on the inner ring. The design effectively seals in lubricant, seals out contaminants and prevents airflow through the bearing. Friction is negligible and the bearing may be run up to the life limit imposed by the lubricant.

TEST RESULTS

Barden Flexeal bearings have been operated up to 3,000 hours at 80,000 rpm in portable grinders. Flexeal stands up under lineal speeds of 6,000 feet per minute, as against 2,000 to 3,000 fpm limits of most other rubbing seals. Operating temperatures range up to 300°F.

AVAILABLE NOW

Flexeal bearings are now available in ten unflanged and four flanged sizes from .3125″ to 1.8504″ O.D. For further data, ask for Flexeal Data Sheet F-1.

Barden is a major producer of precision ball bearings for instruments, weapon systems, computers and other high quality equipment.

for reliability...specify

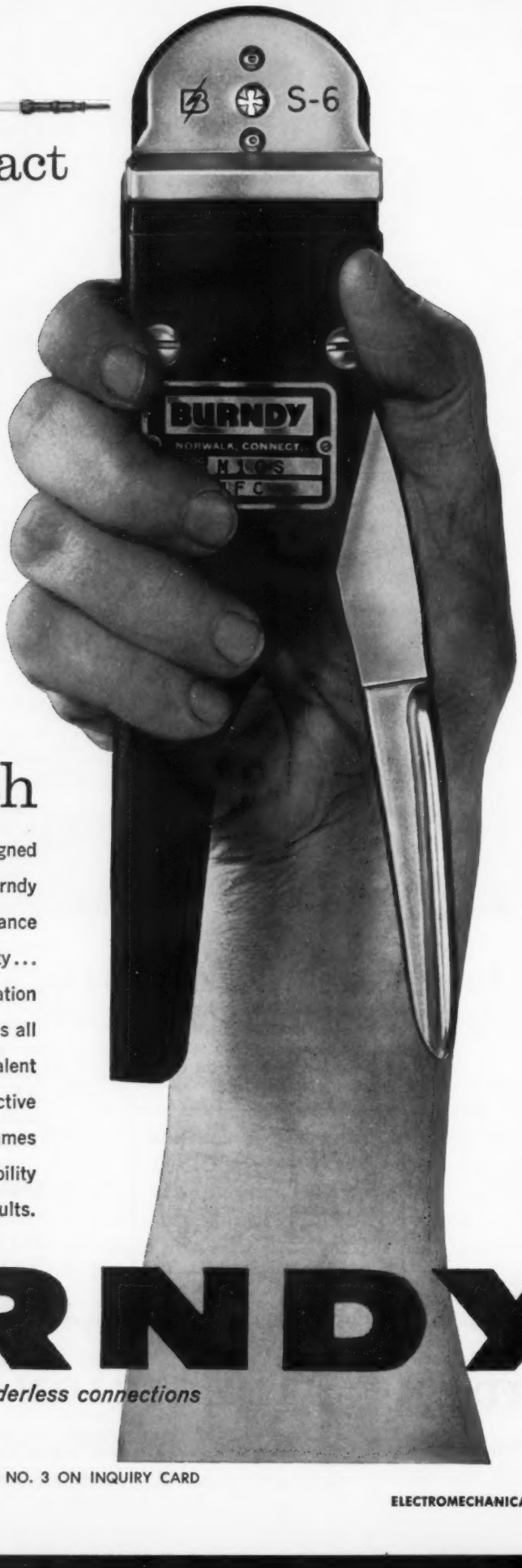
BARDEN PRECISION BALL BEARINGS

THE BARDEN CORPORATION, 206 Park Ave., Danbury, Conn. Pioneer 3-9201
Western Office: 3850 Wilshire Blvd., Los Angeles 5, Calif. DUnkirk 5-0034

CIRCLE NO. 2 ON INQUIRY CARD

the tool

the contact



both

Contact AND tooling designed
and produced by Burndy
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and uniformity...
by the one organization
that devotes all
its creative engineering talent
to this vital objective
and assumes
total responsibility
for the results.

BURNDY

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—for thirty-seven years, the leader in solderless connections

CIRCLE NO. 3 ON INQUIRY CARD

ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

JULY 1961 • VOL. 5 NO. 7

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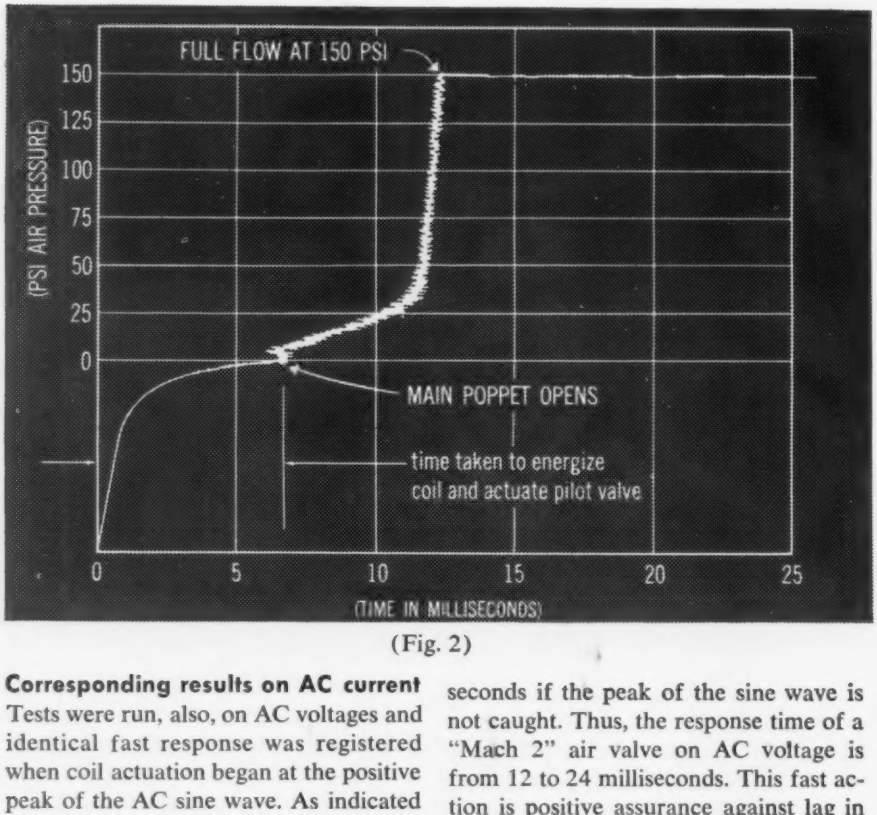
'Mach 2' Air Valve Gives 12 Millisecond Response

Oscilloscope tracks valve action from 0 to full flow at 150 psi

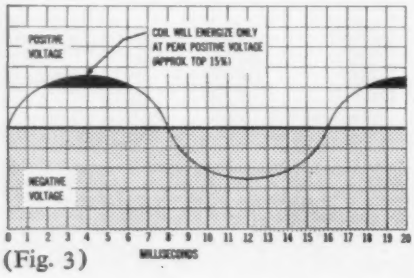
Twelve milliseconds is the time required to energize the solenoid coil, actuate the pilot valve, and bring the main poppet of a "Mach 2" air valve into fully open position at 150 psi. To record the instant response that eliminates lag in air-automated operations, a Crescent® "Mach 2" 4-way air valve was tested by the American Laboratory, Los Angeles, California. A camera located over the oscilloscope screen (Fig. 1) photographed the response action. Tests were made with a 12 volt DC coil in the de-energized position, poppet No. 1 in the closed position, and a system pressure of 150 psi. The graph (Fig. 2) was drawn from a photograph of the oscilloscope screen. The curved line in the lower section of the graph indicates the time required to energize the coil and actuate the pilot valve. The heavier line, above, is the oscilloscope's registration of the increase in pressure as poppet No. 1 moved from closed position to full open position where 150 psi line pressure was reached. Total elapsed time is 12 milliseconds.



(Fig. 2)

Corresponding results on AC current

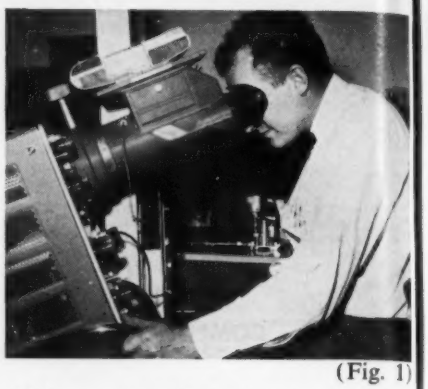
Tests were run, also, on AC voltages and identical fast response was registered when coil actuation began at the positive peak of the AC sine wave. As indicated in Fig. 3, a wave length of AC current is approximately 16 milliseconds in duration. A coil will not energize until voltage has reached approximately 85% of capacity. The energized period represents 15% of the sine wave or 4 milliseconds. Therefore, additional milliseconds will be added to response time up to 12 milliseconds if the peak of the sine wave is not caught. Thus, the response time of a "Mach 2" air valve on AC voltage is from 12 to 24 milliseconds. This fast action is positive assurance against lag in operations where instant response is imperative – sorting, counting, discarding sub-weight containers, spot welding, etc.


POSITIVE VOLTAGE
COIL WILL ENERGIZE ONLY AT PEAK POSITIVE VOLTAGE (APPROX. TOP 15%)
NEGATIVE VOLTAGE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
MILLISECONDS

(Fig. 3)

High speed PLUS dependability

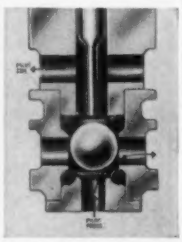
The fast response of "Mach 2" air valves is attributable to original design advances that also dramatically improve endurance. These new air valves are rated at 1000 cpm continuous duty, and cycling speeds to 2100 cpm have been maintained for intermittent periods of 20 minutes. Control of coil heating and drastic reduction of friction in the solenoid and pilot valve sections are essential for this kind of performance. The extremely short stroke of the "Mach 2" solenoid plunger (3/32" – approximately the thickness of a nickel) fractions the time the coil is energized; heat generation drops and response is stepped up. Coil life is guaranteed for a minimum of 100 million cycles.



(Fig. 1)

Friction drastically reduced

In the pilot valve, a tiny ball seats on "O" rings at both ends of a pilot cartridge. The ball moves freely, independent of the seals. There is no "O" ring drag on the pilot plunger because it requires no seals; where there is no friction there can be no wear. The main valve seats seal on "O" rings, and metal shoulders take the shock in such a way that the "O" ring seal is merely kissed by the seat in the sealed position. As the rings are only minutely flexed, they do not fatigue or lose their resilience.



PILOT CARTRIDGE

Write for your "Mach 2" catalog

The 12 millisecond response and long service life of "Mach 2" pilot operated air valves are sound recommendations for the installation of these field proven units. They are available in ¼" to ¾" pipe sizes. For your "Mach 2" catalog write to Barksdale Valves, 5125 Alcoa Avenue, Los Angeles 58, California.

"Mach 2" 4-Way Valve

CIRCLE NO. 4 ON INQUIRY CARD

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A NEW, SMALLER TEMP. CONTROL PRICED FOR THE OEM

ASSEMBLY PRODUCTS INC.
CHESTERLAND 79, OHIO

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ALITE® HIGH-ALUMINA HERMETIC SEALS AND BUSHINGS

Combine...

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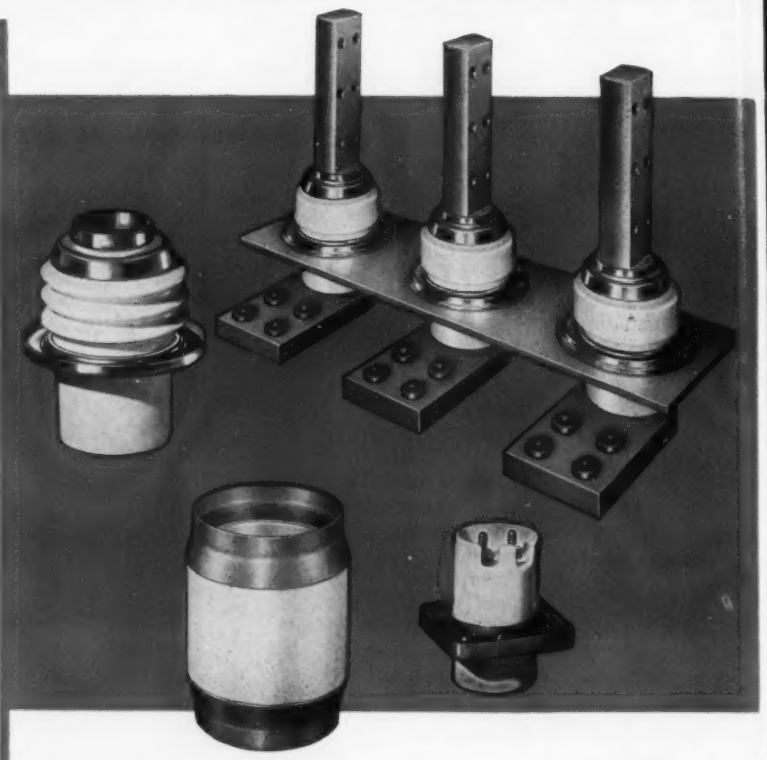
- SUPERIOR MECHANICAL STRENGTH
- HIGH TEMPERATURE AND HEAT-SHOCK RESISTANCE
- RELIABLE ELECTRICAL CHARACTERISTICS
- HIGH RESISTANCE TO NUCLEAR RADIATION
- PRECISION TOLERANCES



Transformer bushings (both high and low voltage) . . . underground cable insulators . . . power cable end seals . . . switchgear contact insulators — these are just a few of the places where Alite is solving reliability and maintenance problems for the electrical industry.

With maximum working temperatures in the range 1300°-1600°C., Alite can be metallized and brazed to metal parts to form rugged, vacuum-tight seals which, in turn, can be welded into final assemblies.

From design to finished part, every manufacturing step — including formulating, firing, metallizing and testing — is handled within our own plant and carefully supervised to assure strict adherence to specifications, utmost uniformity and reliability.

★ ★ ★ ★

The Alite parts and products listed at the beginning of this advertisement are typical of the special design problems on which Alite engineers stand ready to help. In addition, over 100 standard sizes of Alite bushings in a range of types are also available to simplify design problems, speed delivery.

Write for FREE Helpful Bulletins

Bulletin A-7R provides detailed description and specifications of Alite. Bulletin A-40 describes Alite facilities and complete line of standard bushings.

389-G

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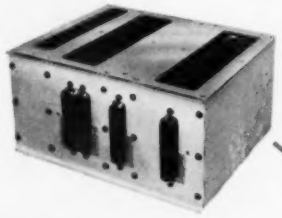
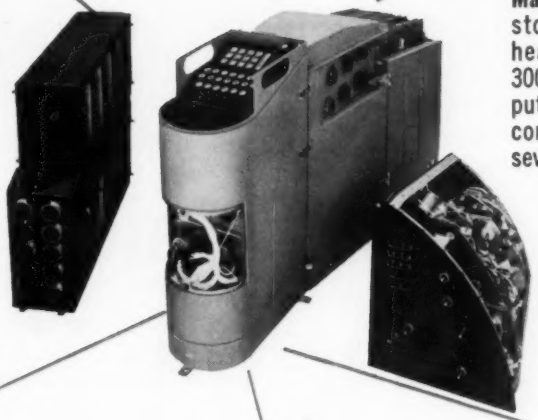
BLOCKS FOR YOUR HOUSE OF DIGITS...

LITTON DIGITAL COMPUTER COMPONENTS



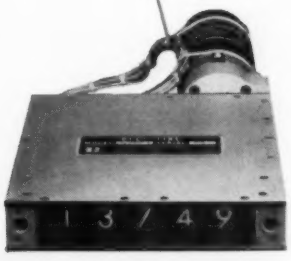
Operational airborne general purpose digital attack navigation computer system. One of many systems through which Litton computer components have been developed.

Magnetic Core Memories. High-speed. Random access. Linear selection. For airborne or other environments. State-of-art two-microsecond read-write cycle.

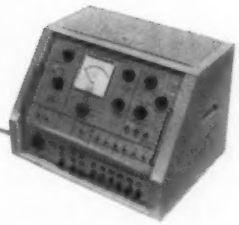


Magnetic Drums. Nickel cobalt storage medium and contact heads. Typical specifications: 300 bits/inch, 500 millivolt outputs, 100 milliampere P.P. recording currents. Suitable for severe environments.

Shaft Encoders. Miniaturized analog-to-digital converters. Extremely small, light, rugged, reliable. Low torque permits weight and volume savings in associated servo components.



Deci-Line Digital Readouts. Lightweight, small, high-speed, alphanumeric, in-line. Digit displayed within .3 second. Serial and parallel.



Test & Support Equipment. Clock track and drum fill recorders, shaft encoder tester, tape editor, card tester, servo tester, and Bace.

Direct inquiries to Marketing Department Special Products, Litton Systems, Inc., Guidance and Control Systems Division, 5500 Canoga Avenue, Woodland Hills, California.

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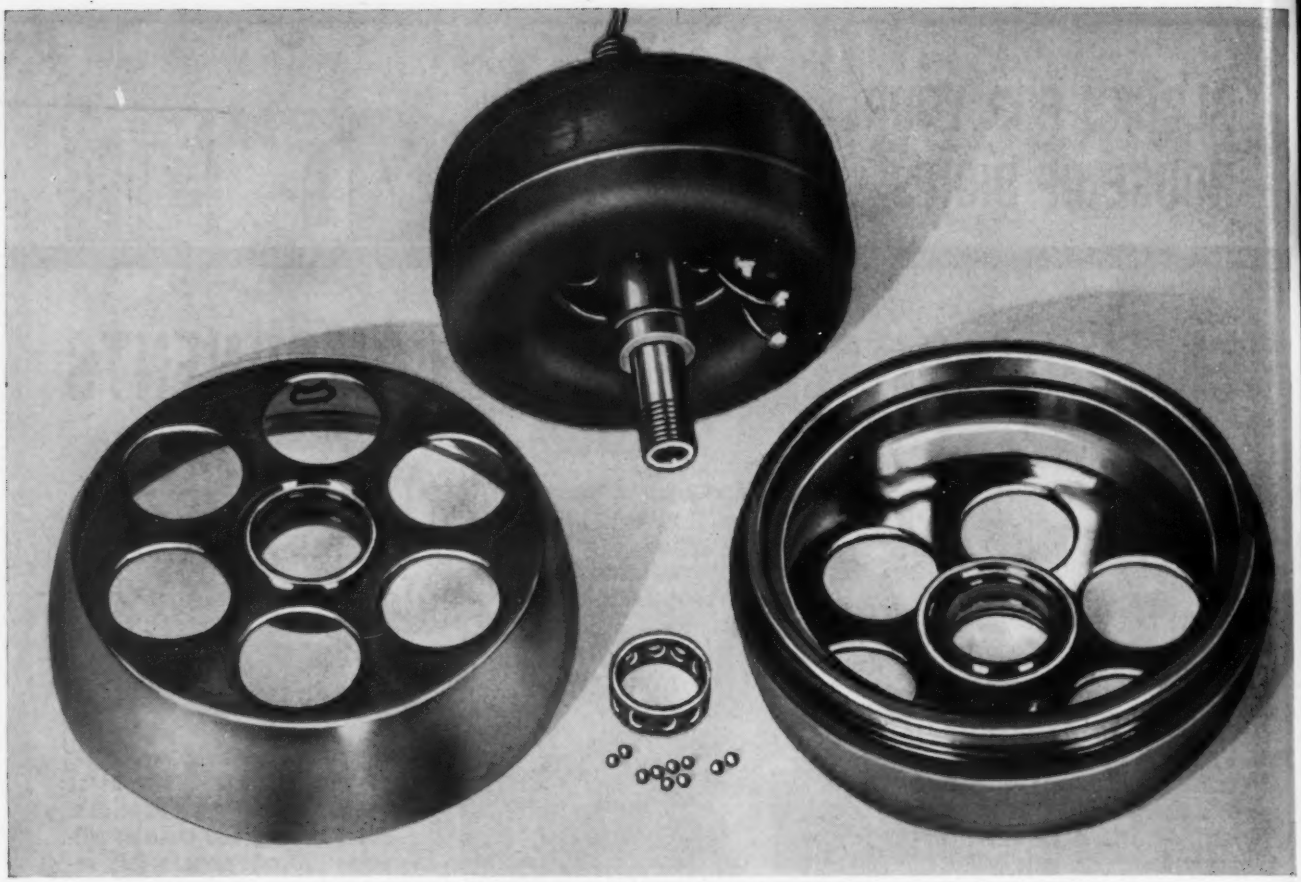

Gyro spin motor shown partially disassembled, produced by Fafnir for B-58 Hustler Bombers

FAFNIR precision bearings help steer the Hustler

Instrument bearing problems? Fafnir has ball bearing engineers who specialize in solving them. But a leading instrument maker recently asked for help of a different order — production of complete gyro spin motors for the inertial guidance systems of Convair B-58 Hustler bombers. By manufacturing the complete "package", Fafnir was able to produce motors that measured up to the precision standards the customer had been seeking.

An unusual assignment for a ball bearing manufacturer. But one that shows the engineering resources Fafnir has at its command. Worth bearing in mind when you have instrument or miniature ball bearing problems! The Fafnir Bearing Company, New Britain, Connecticut.

CONVAIR B-58 HUSTLER, WORLD'S FIRST SUPERSONIC BOMBER

FAFNIR
BALL BEARINGS

CIRCLE NO. 8 ON INQUIRY CARD

Now, you can save time and insure reliability... by specifying DK Coaxial switches in your design

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And, don't forget that RF Products, pioneers in the development of the coaxial switch, will continue to offer you design and engineering services whenever you need them. Whether you order a switch from the catalog or a switch designed to meet your exact specifications, you can be assured of the same high quality and service.

For details on our new line of standard switches, write for catalog DK 61.

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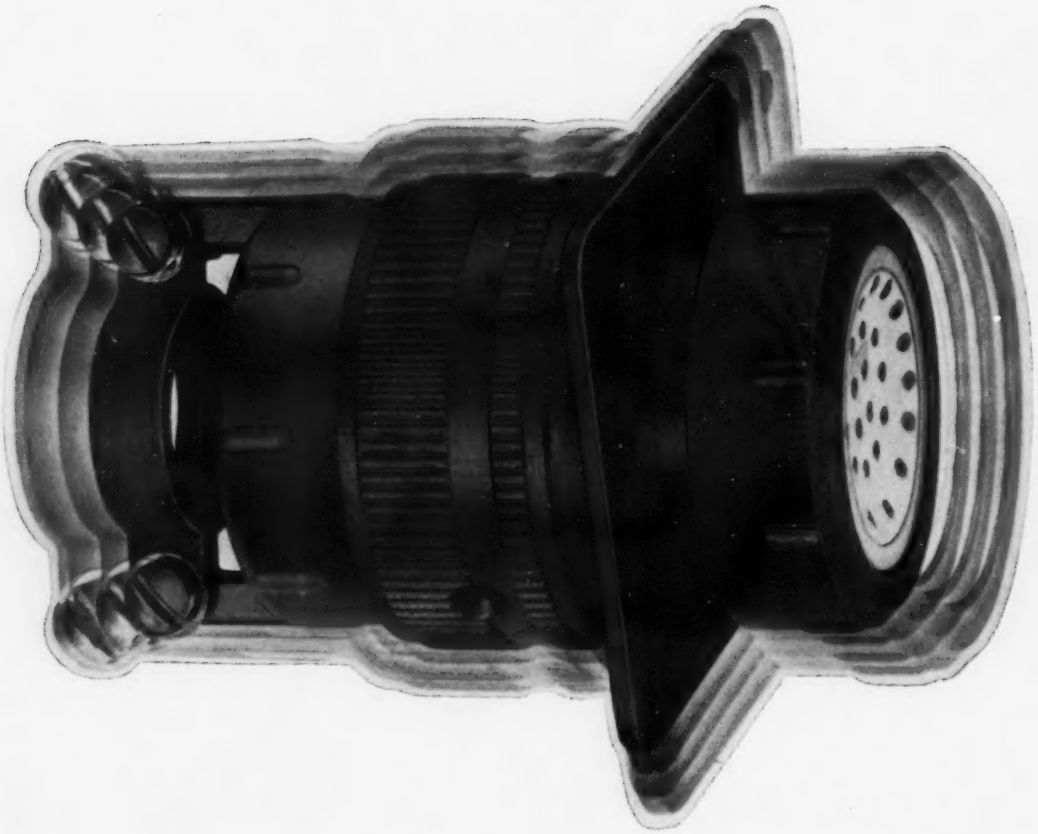

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CANNON PLUGS

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A NEW STANDARD IN 10-TURN POTENTIOMETERS

CLAROSTAT

SERIES 59M14

A new high in potentiometer capabilities ... the Clarostat Series 59M14, 10-turn, ⅞" potentiometer packs more performance per cubic inch than any other multi-turn pot today. Clarostat's unique design permits more winding length in a given diameter than conventional designs. And, price-wise, the Series 59M14 is competitive across-the-board.

For all your multi-turn potentiometer needs, compare Clarostat for quality, for value...

SPECIFICATIONS — SERIES 59M14, 10-TURN POTENTIOMETERS

• Diameter	⅞"
• Length	1.55" (Bushing) 1.611 (Servo)
• Maximum Resistance	100,000 ohms
• Indep. Linearity	± .25%, To ± .05%
• Wattage	4.5 watts @ 40° C.
• Taps	Center tap
• Rotations	3600 + 10 − 0
• Maximum Torque	1.0 oz. in.
• Weight	1.0 oz.

WRITE FOR COMPLETE DETAILS

CLAROSTAT®

Compare

CLAROSTAT

CLAROSTAT MANUFACTURING CO., INC.
DOVER, NEW HAMPSHIRE

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SEMICONDUCTOR PHOTOSWITCH

PNPN Switch Performs Dual Role of Light Sensing and Load Actuating

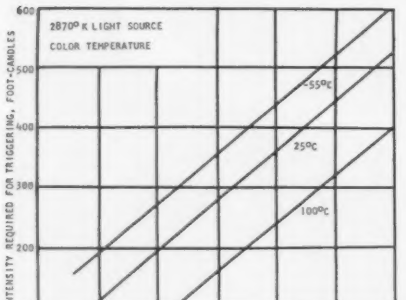

Fig 1 Light intensity required to trigger the photoswitch can be set electrically by changing the gate bias current.

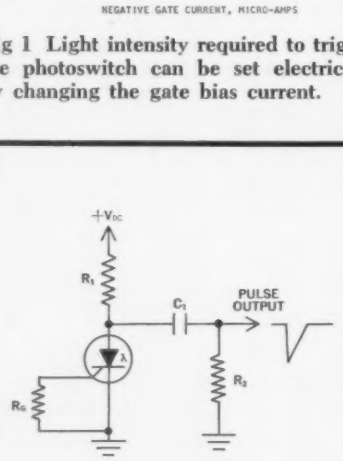

Fig 2a Negative pulse output.

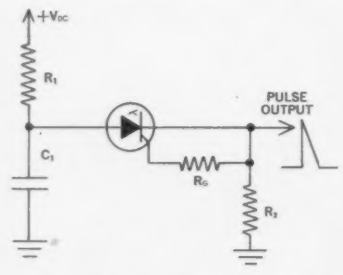

Fig 2b Positive pulse output.

Relays, mechanical switches, amplifiers, thyratrons and related components can now be eliminated in design of many types of control systems by use of a new photocell called Photran, to achieve less complex, smaller and more reliable equipment. The new device, manufactured by Solid State Products, Inc. of Salem, Mass., can be characterized as a bistable photoswitch with many properties similar to those of a gas thyratron. Its output is determined primarily by the load and is independent of light input at all intensities above the triggering level.

Essentially a PNPN switch triggered by light energy instead of (or in addition to) electrical energy, it can often perform the dual role of light sensing and load actuating. Before light strikes the Photran it is in a high impedance (over 10 megohms) "off" state. When a light impulse is applied, it switches to a low impedance (under 10 ohms) "on" state and remains "on" until electrically turned "off". The light energy used to trigger the device "on" need only be momentary since it is not required to sustain the device in the "on" state.

Photran's active element is 0.06 x 0.06 inches and is solidly attached to its mounting base. The enclosure is a glass to metal hermetic seal to give permanent protection against all contamination. The unit meets the requirements of Mil-S-19500 B, and can be operated over the temperature range of −65 to +125°C.

HIGH POWER OUTPUT

Power dissipation rating of the Photran is 0.25 watts at 25°C ambient and 0.5 watts at 75°C case temperature. Its voltage drop when "on" is below 1.5 volts at all current levels under 300 mA.

Load power delivered by the Photran can be as high as 60 watts continuous (200V − 300mA) at an efficiency as high as 99 percent. Peak pulse current up to five amperes can be supplied in circuits which operate at sufficiently low duty cycles to stay within the average power rating of the device. Thus miniature size can be combined with high current–high power output for the first time in a photocell.

FAST RESPONSE

Time required to turn "on" the Photran is directly related to the light intensity used for triggering. When the light intensity is at the minimum required level, the turn–on time is typically 10 microseconds. This time can be reduced to below 1 microsecond by a sufficient increase in light intensity. Turn-off time is primarily controlled by the recovery time of the device (typically 30 microseconds). In comparison to most other photocells, this response time is fast and permits the design of high speed control circuits.

BINARY MEMORY

A property of the Photran which is perhaps most unique and intriguing is its binary memory. Once light has triggered the device "on", it will remain on indefinitely until electrically turned "off" by reducing its anode current to zero. In effect, the device "remembers" that a light pulse exists. This property can be put to work in a variety of electro-optical control and logic systems designs.

TRIGGERING

Light intensity required to trigger the new photoswitch can be set electrically by changing its gate bias current. Fig 1 shows this relationship. Note that a wide control range exists which allows very simple adjustment of the Photran circuitry to adapt to a wide variety of light sources. It also permits setting the threshold level for triggering well above any undesired ambient illumination.

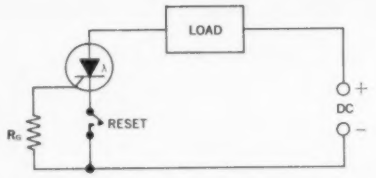

Fig 3a Simple control circuit using dc source power. The Photran acts as a light actuated latching switch. When light strikes the Photran, power is applied to the load. The Photran continues to conduct when light has been removed. Load power is turned off by a reset switch or similar function.

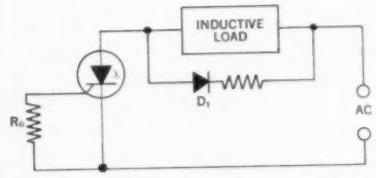

Fig 3b Simple control circuit using an ac source provides half wave rectified dc to the load when light is applied and no output when light is removed. A diode, D_1, is used when the load is inductive such as in a relay or solenoid coil. The diode eliminates inductive voltage build-up and, equally important, allows the energy stored in the inductance during the positive half cycle to be returned to the load during the negative half cycle. The diode polarity is such as to allow the induced current to flow through the load in the same direction as during the positive half cycle. This free wheeling action provides a continuous dc current through the load for both half cycles.

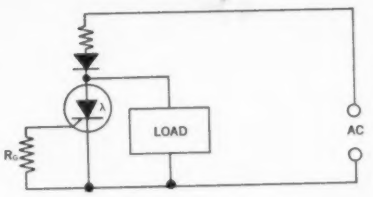

Fig 3c This circuit provides power to the load when no light is on the Photran, and removes load power when light is applied.

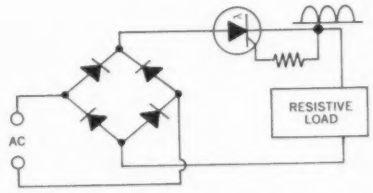

Fig 3d Gated bridge circuit provides full wave dc to the load when light is applied.

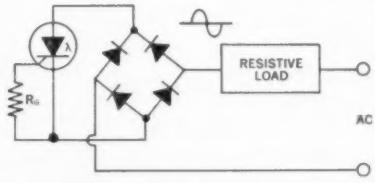

Fig 3e Gated bridge circuit similar to 3d except here the output is full wave ac.

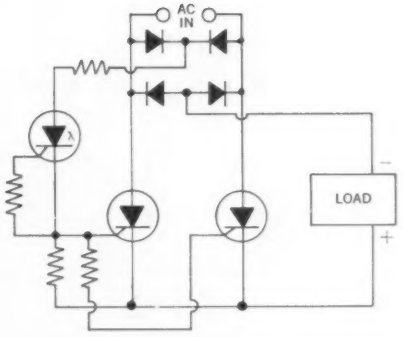

Fig 4a High power output circuit supplies full power when light is applied to the Photran. There is no output when light is removed.

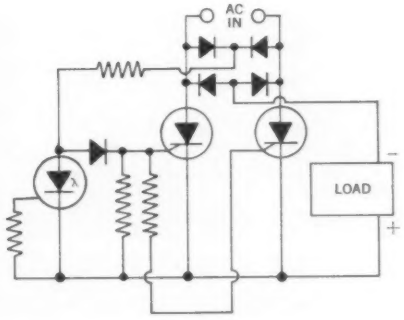

Fig 4b High power output circuit provides power to the load when light is removed and no power when light is present.

This bias control property of the device allows simple electrical gating. By setting a high bias level, the unit can be made non-responsive to light, and by subsequently reducing the bias, it can be made to react normally. This permits many complex programming functions to be accomplished simply.

The fact that electrical triggering can be used in addition to optical triggering makes possible an electrical-optical logic "or" gate.

Sensitivity of the device is affected by the color temperature of the light source. The spectral response is similar to other silicon photo devices ranging from 0.4 to 1.1 microns. Maximum sensitivity is at approximately 0.85 microns.

PULSE GENERATOR APPLICATIONS

In counting, sorting, timing, indexing and programming systems, obtaining a discrete pulse output for each interruption of light at the photocell input is often desired. The pulse generator circuits in Fig 2 provide a single pulse output each time a light beam has been removed and subsequently reapplied to the cell.

One mode of circuit operation is for light to be continuously on the cell. Under this condition the Photran conducts a small amount of current (under 100 μ) continuously through R_1 which prevents C_1 from charging. When the light is temporarily removed from the cell, it drops out of conduction and C will charge to the supply voltage through R_1. When light is subsequently applied, the Photran is triggered on and discharges C_1 through R_2 and the load.

An alternate mode of operation is by light impulse. In this case, light is normally not present on the cell and C_1 is fully charged. When a light impulse occurs, C_1 is discharged through R_2 and the load. C_1 recharges after the light impulse terminates.

For either of these modes of operation, the amplitude and width of the output pulse are set by circuit values and are independent of light intensity.

SIMPLE CONTROL CIRCUITS

The Photran can be operated from ac as well as dc power sources. When ac is used, the unit will block during the positive half cycle when it has not been triggered by light, and will conduct when it has been triggered by light. During the negative half cycle, the unit acts as a blocking diode regardless of whether light is on it or not. If the device has been conducting during a positive half cycle it will automatically drop out of conduction

during the negative half cycle and must be retriggered with light before it will again conduct on another positive half cycle.

The properties of the Photran make it frequently desirable to use ac instead of dc source power. This often eliminates the need for separate dc power supplies and can greatly simplify many control systems. Several simple control circuits are given in Fig 3.

LIGHT ACTUATED POWER CONTROL

In many light actuated control systems, relatively large amounts of power to a load from photocell inputs are required. In these cases a Photran could be used to actuate a power relay with one of the simple control circuits previously discussed. Relays, however, have a limited life and can prove unreliable when hundreds of millions or billions of repeat cycles are involved. In applications of this nature, where the highest reliability is desired, the Photran can be teamed with Silicon Controlled Rectifiers (SCR) to achieve highly efficient light actuated power control.

Two high power output circuits are shown in Fig 4. Both circuits provide full wave dc output to the load. In both of these circuits, the Photran controls the gate voltage to the SCR's. The Photran is capable of supplying the necessary gate firing power to all currently available SCR's including those with ratings up to 70 amperes. Thus tens of kilowatts of load power can be controlled with this simple yet highly reliable circuitry.

LOGIC CONTROL CIRCUITS

Many types of logic control functions can be performed using the binary memory property of the Photran. Fig 5a is a light actuated "and" circuit. In this case light must strike all three Photrans simultaneously for power to be applied to the load. As many Photrans as desired can be used in this circuit so it may be adapted to a variety of input requirements.

A modified version of Fig 5a is shown in 5b. This is a light actuated "sequential-and" circuit. In this case power is applied to the load after light has been applied to all three Photrans. However, in this arrangement, the light impulses do not have to be simultaneous. Each Photran will "remember" that it has received a light impulse by turning "on" and remain-

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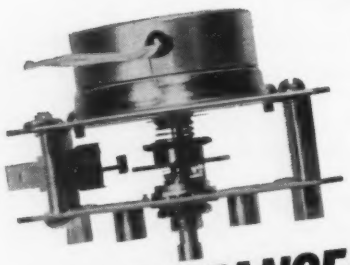

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Min. BV_{CER}	(I_{CE} = 10mA, R_{BE} = 10Ω)	25v	25v	15v	15v
Min. BV_{EBO}	(I_{EB} = 10μA, I_C = O)	5v	5v	5v	5v
h_{FE}	(I_C = 3mA, V_{CE} = .4v)	20-60	40-120	20-60	40-120
Max. V_{CE}	(I_C = 3mA, I_B = .3mA)	.25v	.25v	.15v	.15v
Max. t_{ON}	(I_{B_1} = 3mA, I_{B_2} = 1mA, V_{CC} = 3v, R_L = 270Ω)	15nsec	15nsec	15nsec	15nsec
Max. t_{OFF}	(I_{B_1} = 3mA, I_{B_2} = 1mA, V_{CC} = 3v, R_L = 270Ω)	25nsec	25nsec	25nsec	25nsec
Max. t_S	(I_{B_1} = I_{B_2} = I_C = 10mA, V_{CC} = 10v, R_L = 1k)	15nsec	15nsec	12nsec	12nsec

Full technical specifications available on request. Write, wire or call:

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61-5

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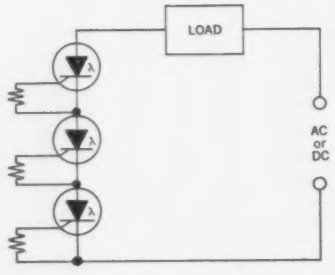

Fig 5a Light actuated "and" circuit.

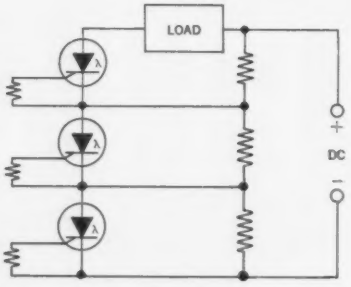

Fig 5b Light actuated "sequential-and" circuit.

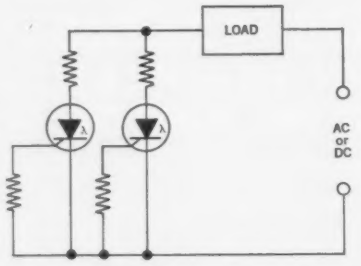

Fig 5c Light actuated "or" circuit.

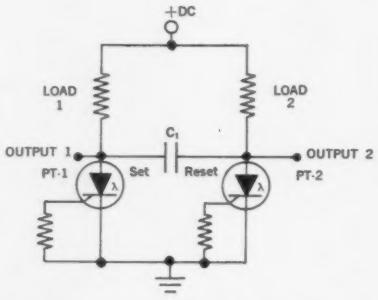

Fig 5d Light actuated power flip-flop.

ing "on". Again, as many Photrans as desired can be used in series to adapt to different input requirements.

Fig 5c shows a simple "or" circuit. Here, the load is actuated when light strikes either Photran. More than two Photrans can be put in parallel to adapt to any desired input arrangement.

Fig 5d is a light actuated flip-flop. When light is applied to *PT-1*, it is turned on, and through the discharge of C_1, *PT-2* is turned off. When light is applied to *PT-2* the action is reversed. *PT-2* turns on and *PT-1* is turned off. • • •

Write No. 255 in Box on Inquiry Card

Pulse Totalizing System

Totalizing a multiplicity of simultaneous pulses on parallel signal lines with a high degree of accuracy is possible with an anti-coincidence system developed by the Programation Div. of Guardian Electric, Chicago, Ill. It consists of a transistorized high speed acceptor module, housed in a convenient plug-in form for each channel. Such modules accept signal pulse rates up to 1000 pps., at energy levels in the order of micro watts, and are capable of momentarily storing a pulse. A time rate demodulator is synchronously driven by a time base and accepts the stored pulse of each acceptor output, delivering these pulses serially to the count channel where pulse level is increased sufficiently to drive the totalizer. Where recording or printout is desired, with or without time base marking, a conversion system module converts decimalized totals to any desired coded output, and channels to the print source. Guardian Electric Mfg. Co., Chicago, Ill.

Write No. 555 in Box on Inquiry Card

PTC THERMISTOR

Low Cost Temperature Control

In our January 1959 issue we reported that Westinghouse Electric was using a new thermal switch, called a Positive Temperature Coefficient Thermistor, to prevent the overheating of their hermetic motors. These PTC thermistors, which can be used to make a very low cost temperature stabilization system in many applications, are now available as individual components from the Semiconductor Dept. of Westinghouse, Youngwood, Pa. The device is a thermally sensitive resistor made from semiconductor materials which have greatly different conducting states for temperatures above and below a predetermined transition temperature. Two types (802-1 and 802-5), with switching temperatures of 105 and 115°C respectively, are available.

Fig 1 illustrates the resistance/temperature characteristic of Type 802-1 PTC thermistor. When connected to a source of steady voltage, the thermistor's surface temperature remains relatively constant in the presence of large changes in ambient temperature. The temperature difference between the thermistor surface and ambient air is determined by the power dissipated in the thermistor and the dissipation constant of the configuration (temperature rise above ambient per unit of power dissipation). At high-ambient temperatures, those corresponding to the steep upper portion of the curve in Fig 1, the thermistor resistance is high. Consequently, it dissipates only a small amount of power from the source, and its temperature rise above ambient will be low.

At lower ambient temperatures, the resistance of the thermistor tends to be much less. At a lower resistance, however, the device dissipates more power from the source and has a larger temperature rise above ambient. Thus, a change in ambient produces a lesser change in thermistor surface temperature because of increased thermistor dissipation and temperature rise. Consequently, a measure of temperature stabilization has been achieved due to the small change in thermistor surface temperature as compared to the ambient change. If an electronic component such as a temperature-sensitive diode or crystal is attached thermally to the thermistor surface, it will be subjected to temperature variations much less than the variations in ambient temperature. This principle of temperature stabili-

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VALVE SHOWN ACTUAL SIZE

- Now designers of pneumatic and hydraulic control systems and devices requiring high flow in smaller packages can **specify miniature solenoid valves from shelf stock.**
- These new B Series valves are so small and so new that ⅛" NPT was too large, therefore 1/16" PTF connections were selected. Fittings are included to make fluid connections with ⅛" tubing.
- Never before have there been valves like this—**really miniature in over-all size, pipe size, and weight.**

VITAL STATISTICS

Type	3-way normally closed
Over-all size	1" x 2 1/16"
Orifice size	3/64" Inlet and Outlet
C_v factor	.045
Fluid connections	1/16" PTF (adapted for ⅛" tubing)
Weight	5 oz.
Maximum operating pressure	150 PSI
Vacuum	Down to 5 microns

Skinner Distributors are now stocking the first of these new valves—the three-way normally closed. Three-way normally open and directional control, two-way normally open and normally closed, and higher pressure models will be on the market soon.

For complete information contact a Skinner Distributor listed in the Yellow Pages or write us at the address below.

B SERIES FEATURES

No leakage—Soft, synthetic inserts provide bubbletight sealing. Seats have smooth rounded edges—no cutting of insert material.

Mounting by means of two tapped mounting holes (8-32) in valve body. Can be mounted in any position.

Voltage—Coils available in most AC and DC voltages. Heat rise meets U.L. standard of 85°C maximum for continuous duty. Maximum power requirement—7 watts.

Electrical housings are available with single grommet or ¼" NPT conduit which can be rotated 360°.

Media—B Series valves may be used with all common media including many semi-corrosive fluids.

Corrosion-resistant—Stainless steel body and internal parts.

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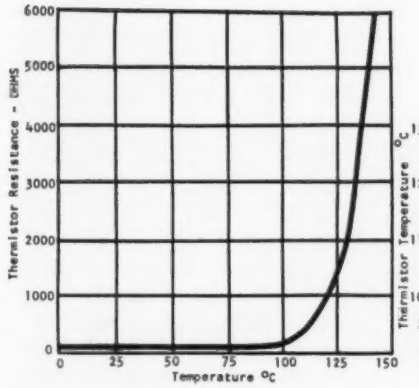

Fig 1 Resistance/temperature characteristic of Westinghouse's Type 802-1 Positive Temperature Coefficient Thermistor. Increase in resistance occurs abruptly, within predetermined temperature bands. The switching characteristic makes the device particularly useful in control and indicating circuits.

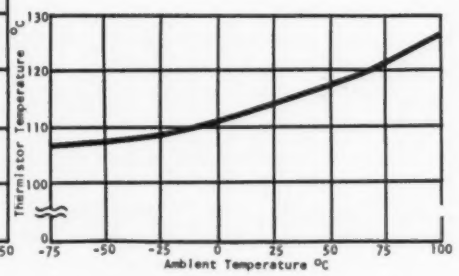

Fig 2 Performance of Type 802-1 PTC thermistor when connected to a 30 volt power source in free air with a dissipation constant of 15 milliwatts per degree centigrade rise.

zation can be extended to larger volumes by employing multiple thermistors and thermally insulated enclosures.

As a practical illustration, the performance of Type 802-1 has been calculated when connected to a 30 volt source of power in free air with a dissipation constant of 15 milliwatts per degree centigrade rise. This performance is plotted in Fig 2. As shown, an ambient temperature change of 136°C from −65C to +71°C produces a thermistor surface temperature change of only 16°C (106°C to 122°C). Thus, for any device whose temperature is determined by thermistor surface temperature, the ambient variations have been reduced by a factor exceeding 8:1.

Roughly the size of aspirin tablets, the thermistors are ceramic pellets surfaced with a metallic coating. They are fitted with leads and coated with a high temperature resin.

PTC thermistors can be used with frequency control elements, voltage regulators and detectors, low level amplifiers, instruments, and various types of circuitry in both military and industrial applications. They are also of use in non-electronic areas. Although this simple scheme will certainly not replace accurate temperature control ovens, Westinghouse believes that it makes possible a marked reduction in the effects of environmental temperature changes on critical electronic components — and at a very low cost.

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WORTH FILING

Tunnel Diode Design

16-page handbook on circuit design of the tunnel diode contains sections on the theory of tunneling action; various general circuit considerations; simple switching circuits ('OR' gate; 'AND' gate; 'majority' gate; and 'fan-out' considerations); and 4 common digital circuits including shift register, ring counter, binary counter and memory circuit.

Source: Transitron Electronic Corp.
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Reliability Nomograph

With a new reliability nomograph, semiconductor users can quickly compute the acceptance number for any given sampling plan, predict the success rate from life test data at a 90% confidence level and can also compute a sampling plan for conventional risks. The nomograph contains scales and tables with complete instructions on their use and a glossary of terms.

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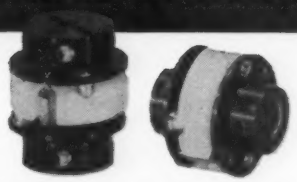
TIC

MINIATURE FLEXIBLE COUPLINGS



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Type MPC-1 consists of two flanged aluminum hubs and nylon or Delrin discs with V-grooves that are displaced 90° with each other. Discs are fastened with stainless steel springs loading ball pivots against V-grooves. Dimensions ⅞ x ⅞ in.
Type MPC-2 has two cylindrical aluminum hubs, each with two ball pivots attached. Hubs are attached to a pair of flexible phosphor bronze discs which hold and load the ball pivots. Dimensions ¾ x ½ in. Both types have range of bores to accept shafts from .120" to .250" and meet MIL-E-4970 and withstand −80° to 200°F and shock to 100 G.

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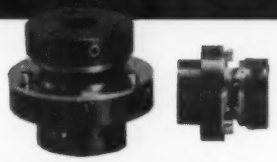

FEATURE • Adjustment over a wide torque range • Compactness and lightweight

Type ASC-1 is ⅞ x 1"
Type ASC-2 Miniature is ⅝" x ⅝"
Both are constructed of aluminum hubs, Delrin* on stainless steel clutch plates and stainless steel hardware. These rugged, high performance clutches are friction units to protect components against excessive or inertia shock loads. Range of bores to accept shafts from .120" to .250". These clutches meet MIL-E-4970 specs.

For details on couplings or clutches write

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DYNAMIC TESTING OF INDUSTRIAL INSTRUMENTS

By: **Allan R. Catheron,** *The Foxboro Co., Foxboro, Mass.*

Industrial instrument design is primarily a problem of adaptation — to the almost universal non-linearities in practical working systems, to noise and fluctuating power sources and varying ambient conditions, and above all to the unknowns that are inevitable in an industry where much of the process information is proprietary. Industrial instrument designers use dynamic testing to increase the scanty store of knowledge about processes and to establish design criteria for making instruments as adaptable as possible. In this article, taken from a paper presented under auspices of the AIEE at a recent Joint Automatic Control Conference at Massachusetts Institute of Technology, Mr. Catheron discusses the factors in industrial control that influence dynamics and the problems in dynamic testing that are peculiar to industrial instrument work.

Industrial instrument makers use dynamic testing in several ways: to evaluate and compare the performances of process control components, to obtain data for predicting the performance of projected control systems and determine the necessary characteristics and adjustments of the components of those systems, and to improve the performance of existing control systems or rectify operating difficulties.

An almost complete lack of quantitative knowledge of the dynamic characteristics of the processes with which industrial instruments are to be used is a major problem confronting the industrial instrument maker. Studies to obtain such process data in the field are therefore a prime activity in dynamic testing whenever the opportunity is available. Although such a study may call for a station wagon full of equipment, and a stay of two or three weeks at the test location, even when only one or two process units are under examination, and despite multi-channel recording to get several responses to one input, the effort is justified. The information obtained includes the dynamic characteristics of several control loops of a piece of process equipment, together with some indication of the degree of their interaction. Most valuable, perhaps, is evidence that similar types of equipment units show similar patterns of performance, even if varying in size and design details.

Difficulties of field test work have influenced some industrial instrument manufacturers to set up "life-size" process units in the laboratory. Such facilities permit dynamic testing under ideal conditions and with complete freedom of choice of operating levels and upsets. They also offer the opportunity to try out new designs of control and measurement units under field conditions yet with laboratory control of the situation.

The range of time constants involved in industrial control work is such that subaudio frequencies are the rule. Extremes of the frequency range of present interest are at 0.0003 cps (about a one-hour cycle) and 100 cps, with 0.0005 to 10 cps rather more common. The low frequencies apply particularly to processes, the higher, obviously, to instrument work.

Thus the dynamic limitations of the system equipment supplied by the instrument manufacturer do not often become seriously involved in the overall stability of the system, and the designer's problem is then that of maintaining internal stability in the device over a wide range of dynamic characteristic adjustments. Only at the high end of the frequency range is there any likelihood of involuntary modification of performance from attenuation, phase lags, and resonances. If we are to keep the limiting frequency a decade above any likely process, and this appears to be the desirable state of affairs, it is necessary to push all these problems above 10 cps.

INDUSTRIAL CONTROL PROBLEMS

Perhaps the most important factor that differentiates industrial control from other servomechanism work (from the industrial point of view, at least) is that the major problem in industrial control is correction for load upsets, with a relatively constant command situation. With a few exceptions, notably cascaded controls, this is the normal state of affairs, the set point remaining undisturbed for periods ranging from a day to a year or more. Another factor that affects designers of industrial control equipment much more than other servo designers is the scarcity of data on the dynamics of the process to be controlled. Because of insufficient application information, the industrial control designer must include a wide range of adjustment in his control devices. Thus the gain and integral and/or derivative time constants of a controller must be adjustable over a wide range of values.

The designer, therefore, must make dynamic tests to determine if the performance of a device is satisfactory over the entire frequency range that may be demanded of it and if it provides sufficient stability and linearity of performance. The question always to be answered is: Will it fit into all probable, or even possible, applications?

This problem has never bothered the

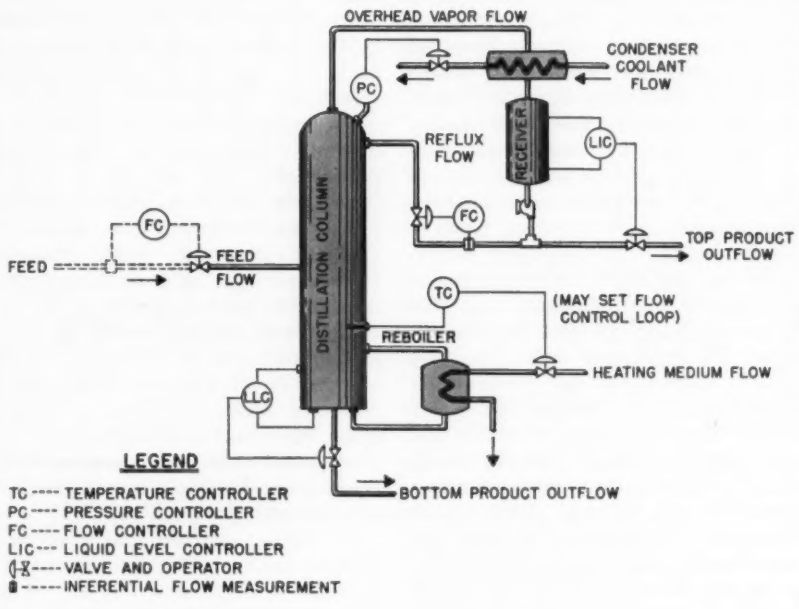

Fig 1 Distillation column control illustrating the interdependence of control loops in an industrial controller. The flow controller on the feed is shown in dotted lines, because it frequently cannot be used, as in the absence of storage capacity between the column and the next unit upstream, which might be a catalytic cracking unit, another column, or polymerization reactors. The fundamental controls for the column are temperature and pressure and reflux flow. All others are to maintain stable conditions. A flow controller is sometimes necessary for the reboiler heating mechanism in place of the simple valve shown, if the heat source pressure fluctuates widely, in order to reduce the disturbances from that source. Changes in the feed rate contribute the worst and most frequent upsets, as a rule, and the next units downstream are subject to whatever variations in product flow may result from the action of the top and bottom product level controllers. An isolated column feeding from and to storage tanks is in an ideal position in this respect from the standpoint of control, but the reduction of storage capacity between units is considered an essential part of designing a process for efficient operation.

designer very much, simply because he is used to the idea. Operative controllers were on the market before the term "dynamic characteristics" was coined, or even expressed as a thought. And the controllers worked. Understanding of system dynamics has been a great help in the design and use of industrial control instrumentation, but it is obviously not indispensable, except insofar as the early control engineers used it intuitively.

NON-LINEARITY

An important factor in the practical application of dynamic testing to industrial instrumentation is linearity, or rather, non-linearity. (For the purposes of this discussion, a linear device may be defined as one that will pass a sinusodial input in undistorted form.) The techniques of dynamic analysis assume linearity in the subject of the test, but practically nothing in the industrial control field is rigorously linear. In operation, nozzle-flapper pressure relationships, control valve characteristics, measuring elements such as orifices and vapor-pressure thermometers are all highly non-linear. Thus all industrial dynamic analysis is an approximation. By keeping test ranges down to a few percent of scale, linear techniques can be used and data can be analyzed by the usual procedures.

This problem applies both to discontinuities in components and to "smooth" non-linearities such as in measuring elements with exponential characteristics. How might these affect the transfer function of the system? What is the maximum amplitude that can be treated as linear? These questions do not lead to answers based on rigorous analysis. Visualization of the degree of non-linearity in the working range of the variable is of help. Limitations, of course, vary with personal experience: our own indicates that an input of plus and minus 1% of the input range is about right. Some take as much as 5%, with the qualification that a much smaller input be used if there is any sign of distortion, the warning of non-linear operation.

Since it is the combination of phase and gain that is vital to the stability of a system, anything that increases the phase lag beyond the classic values is of great importance. Most non-linearities have the effect of increasing the phase lag in a system. While not a true non-linearity, the case of dead time (transportation lag), which contributes phase angle that increases with frequency without any accompanying attenuation, is obviously very troublesome from the standpoint of system stability. In general, it must be assumed when calculating unit performance that the phase will be more than the theoretical because of non-linearities that can be counted upon.

Operators of industrial control systems have similar problems because the non-linearities usually include serious changes in plant gain as operating levels are changed. Readjusting the controller settings with every change of set point is seldom practical, yet if this is not done performance will often be appreciably degraded. Controllers that automatically compensate for such situations have been built experimentally, but they are very rare.

PNEUMATIC EQUIPMENT

The transition from primarily pneumatically-operated devices to electrical and electronic systems is changing the dynamic problems of the designer, at least in one important particular: the effect of transmission lines. However, pneumatic systems have some very real advantages of ruggedness, simplicity, and safely in hazardous atmospheres. So it seems probable that pneumatic and electronic control systems will continue to exist side by side, each used where it serves to the best advantage, for a number of years in the future.

Pneumatic controllers have a major disadvantage in comparison with electronic controls, in that the breakdown of the system into its units (blocks) is so much less clear, and more dependent upon the individual case. Interaction of components is common. For instance, a controller operating a diaphragm type valve motor through a pneumatic transmission line of appreciable length cannot be divorced from

that motor and line dynamically until the line has exceeded a certain critical length dependent upon its bore. (With a small volume termination, the time constant of a given length of tubing approaches a minimum as the bore enlarges, but then increases again. Industrial practice, however, involves only two standard bore sizes, if capillary tubing for pressure thermometer systems is excluded.) The diaphragm motors so commonly used for operating control valves present a distinct problem in that they form a large volume *which changes with the valve position.* The change is often appreciably greater than the initial volume at minimum or zero signal.

INTERDEPENDENT LOOPS

The designer and the user of industrial control equipment are often faced with a fundamental conflict which the writer believes to be rarely present in other servo applications. It stems from the fact that several units of industrial process equipment may be fed from the same source or may be connected in sequence, with material moving from one unit to the next. Also, a single unit of process equipment may have several interdependent though not necessarily interconnected control loops acting upon it. Under these conditions drastic control action in one loop can have reactions on other loops. To think of each control loop as an independent, isolated unit leads logically to strong control action that can change levels on command or correct deviations as rapidly and stably as possible. Viewing the loop as part of a larger picture has the opposite effect: discouraging anything drastic and pointing to weaker, slower control action. Thus the ideal is rapid strong control action that involves little or no change in valve position, a study in contradiction.

Interdependence of several control loops in a single piece of process control equipment is illustrated by the control ordinarily applied to a distillation column, show in Fig 1.

DYNAMIC TEST PROCEDURES

In testing devices for industrial service, frequency response techniques are generally used, although step and ramp inputs are applied when appropriate. Sometimes, for greater accuracy, a combination of tests are used to permit cross checking. A particular instance of this is in determining the time constants of a process. A majority of industrial processes included some dead time (transportation lag) or delay, but it is ordinarily a small percentage of the major time constant. Since the lags of the process exhibit varying degrees of interaction, from the isolation represented by cathode-coupled RC's to the interaction of directly connected RC's, the frequency response curve of such a process does not exactly follow the classic form, but has its corners rather less sharply defined. Of course, the relationship between phase and gain is hardly classic either. It has proved highly desirable to make both step and frequency response tests of such a process. The frequency curves provide an indication of the number and value of time constants, and this can be confirmed, at least for the two longest, by extraction from the step response record by the percent incomplete method (which does break down if the two time constants are nearly equal). Dead time, although appearing directly on a step record, is apt to read high because of the practical difficulty of recording the exact instant when the measurement first makes any change at all (for this is usually below the resolution of the recording equipment). With the time constants identified, it is impossible to obtain a better idea of the dead time by the discrepancy between the theoretical and the actual phase angles in the frequency plot.

Fundamental tools of the trade are the wide-range sine wave oscillator and the multi-channel, high-speed, high-sensitivity recorder. Use of an oscilloscope for an analysis is made difficult by the frequency range involved (even at 10 cps, and with a long-persistence screen, reading Lissajous figures is not easy even with use of a phase-shifting device.) Reduction of data from a permanent chart record is still the most accurate and reliable method. For frequencies below 0.001 cps, a mechanical generator with pneumatic transmitter and/or sine wave potentiometer has been necessary.

Electrical oscillators with the necessary transducers for pneumatic signals are used in the majority of cases for frequencies above 0.001 cps. Measurement pickups for dynamic test work must be selected with considerable care to be sure that their dynamics do not intrude into the problem.

In making an open loop study to determine the controller characteristics required for a process, the signal generator output should, of course, replace the controller output as the input to the rest of the system, which, complete, forms the process. The measurement signal, loaded as the controller would load it, provides the process re-

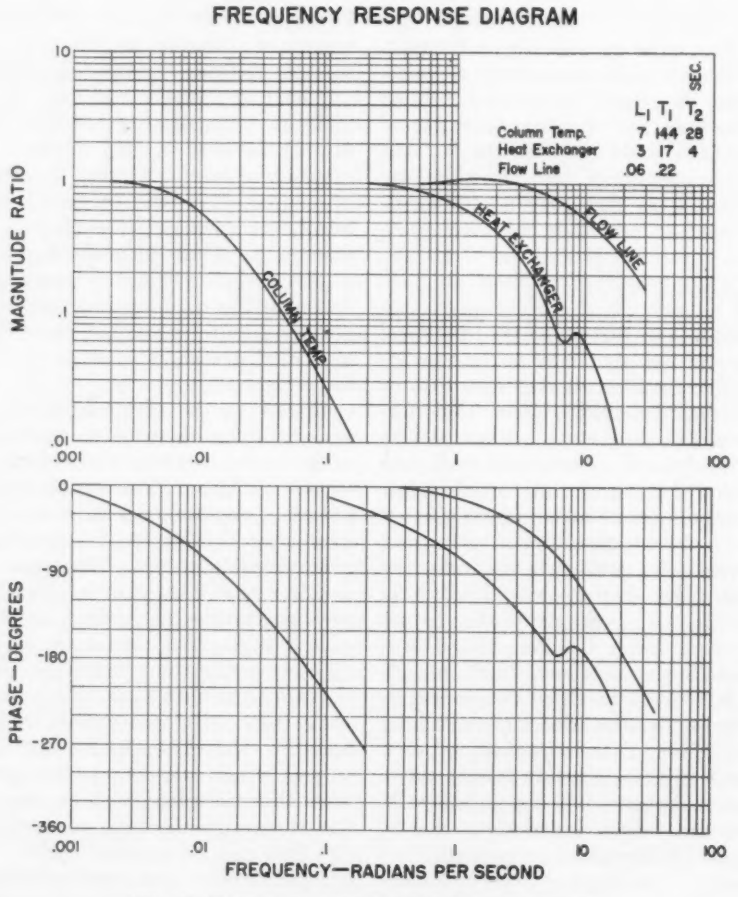

Fig 2 Frequency response of three processes.

sponse record. It is sometimes difficult to break down the system more completely, or to define its parts for synthesis. A pneumatic transmitter should include its transmission line and load (or equivalent load), and the process is often difficult to disassociate from its measuring element.

Data is usually presented and handled in frequency response form as a Bode plot, this being the most practical response and the clearest to the majority of users. Granted that the theoretical ideal is perhaps the transfer function, a transfer function that tells enough about the detailed behavior of a specific device is apt to be awkwardly elaborate. The generalized forms are oversimplified, so that they may skip the important high frequency behavior, or interaction effects. Complete systems work is actually just getting started in the industry. Its advent may produce a considerable increase in the use of the transfer functions.

CHARACTERISTIC PROCESSES

What kind of a response pattern is apt to appear in process tests? Figure 2 presents typical frequency responses of units of process equipment. The slow response on the left is that of the temperature of a distillation column in response to manipulation of reboiler heating steam (Fig 1). A heat exchanger alone (a reboiler is a form of heat exchanger) responds more rapidly, but in a somewhat complex way in this case. A really fast process — the response of flowing liquid in a line to valve manipulation — appears at the right. These examples were selected to illustrate the range of frequencies involved in process control, as well as the varied forms of response.

As a practical matter, the two longest time constants of a multi-capacity process almost completely determine the control characteristics required for stability. Other time constants, if present, are ordinarily so short as to be outside the dynamic range of the system as a whole. Coupled with the fact that service settings are seldom made close to unstable values, this means that a complex process can often be described in rather simple terms for all but the most rigorous analysis and synthesis. Thus, describing a process as one or two first-order time constants, with possibly some dead time and perhaps a second-order resonant response is justified.

Such descriptions in terms of time constants apply directly to (dynamically) simple process units, but less directly to more complex systems.

FREQUENCY RESPONSE DIAGRAM

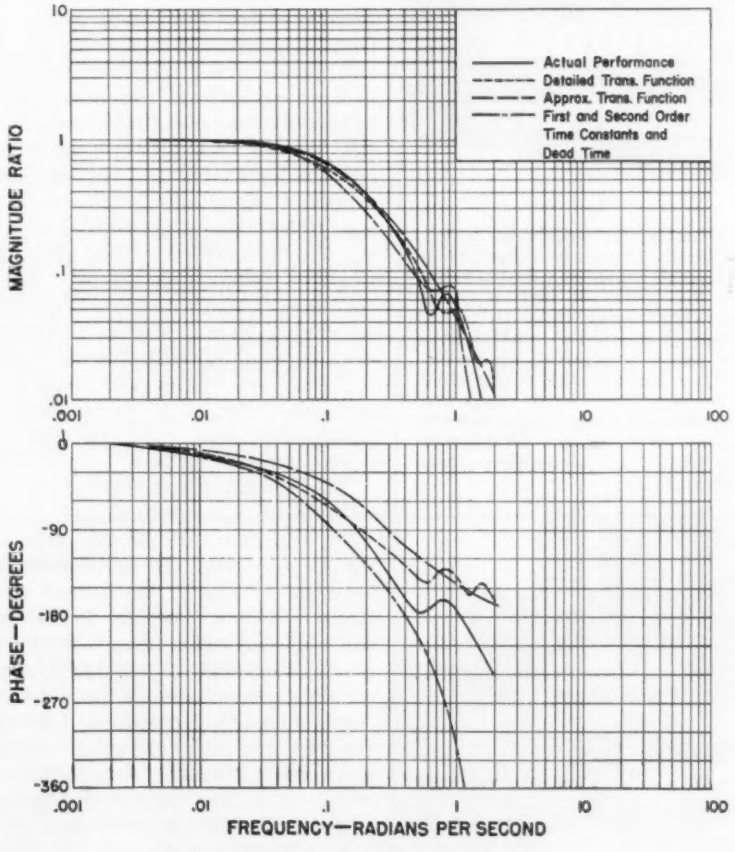

Fig 3 Heat exchanger performance.

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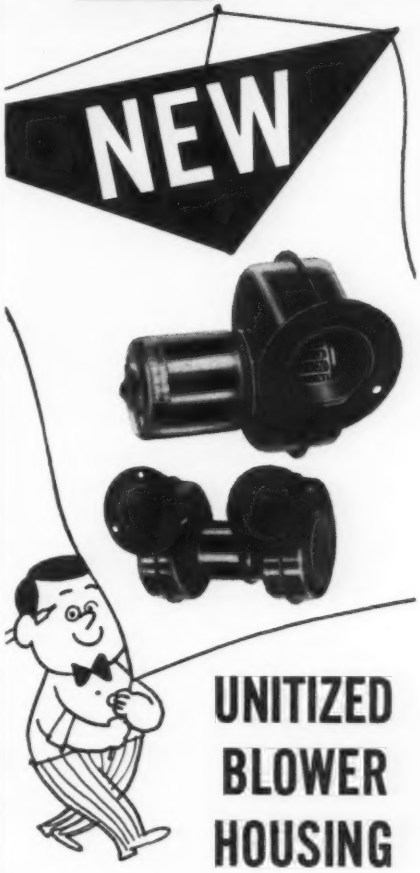

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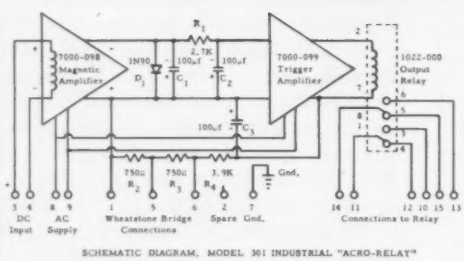

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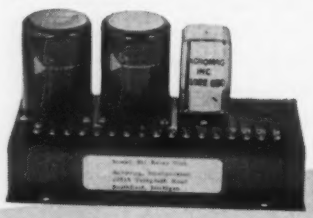

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When we consider the frequency responses of Fig 2, there are the flow process (one first-order lag plus a dead time), the distillation column (two first-order lags plus a dead time) and the heat exchanger (two first-order lags plus the equivalent of a second-order response with $\zeta = 1$ plus dead time). All of these represent the controller's view of the process, in that the final operator of the system, the valve, was manipulated to produce the input signal which is actually the valve stem position. The output signal is the measurement that the controller sees, usually involving the characteristics of the measuring element or transmitter. In Fig 2, the two simpler processes seem to be exactly like their descriptions in terms of time constants, with the possible exception of added shorter ones that do not appear in the tests. The heat exchanger model is more of a tour de force.

Consider now the dynamic characteristics of a heat exchanger. Figure 3 shows how the various derivations of the dynamic response compared with the actual performance as determined by test. This last is indicated in the figure by the solid lines.

The transfer function of this heat exchanger was derived in great detail from its physical dimensions, materials, and performance specifications. From this was calculated the frequency response shown by dotted line in Fig 3; the product of the two transfer functions is presented in Fig 4a. Some simplification is afforded by making a low frequency approximation. The transfer functions for this approximation are presented in Fig 4b, and the derived frequency response is shown by the dashed lines in Fig 3. To calculate even the simplified frequency response requires an appreciable amount of computer time, so a "brute force" approximation was tried on this relatively complex process.

The system described by two first-order lags, a resonance, and a dead time was used. While the gain plots for all the methods fall comfortingly together in Fig 3, the spread of the phase curves is perhaps indicative of the approximations taken. In the case of the two sets of transfer functions, no allowance was made for dead time. Experimentally determined dead times tend to run high: a value estimated from the exchanger construction and water velocities would bring these phase curves in line with the test record. In the greatly simplified case, the large phase lag of the second-order unit

$$G_p = \frac{1}{k_h + D\left[T_p + T_h + \frac{1}{w_o s_{fg}}\left(\frac{pv_{fg}}{h_{fg}J}\right)_o\left(r_a C_w \frac{C}{1+T_s D}\right)\right] + \left(\frac{T_b}{T_{a_2} - T_{a_1}}\right)\left(\frac{pv_{fg}}{h_{fg}J}\right)_o \left(\frac{T_a D + \frac{1 - e^{-\left(\frac{1}{\alpha_a} + T_a D\right)}}{1 + \frac{T_a}{\alpha_a} D}}{1 + \frac{T_a}{\alpha_a} D}\right)}$$

and

$$G_{ab} = \frac{1 - e^{-\left(\frac{1}{\alpha_a} + T_a D\right)}}{1 + \frac{T_a}{\alpha_a} D}$$

Fig 4a Heat exchanger transfer function.

$$G_p = \frac{1}{\left(\frac{T_b}{T_b - T_{a_1}}\right)_o \left(\frac{p_o v_{fg}}{h_{fg}J}\right) + k_h + D\left[T_f + T_p + T_h + \frac{1}{w_o s_{fg}}\left(r_a C_w + \frac{C_s}{1+T_s D}\right)\left(\frac{pv_{fg}}{h_{fg}J}\right)_o\right]}$$

and

$$G_{ab} = \frac{1 - e^{-\frac{1}{\alpha_a}}}{1 + \left(\frac{1}{\frac{1}{\alpha_a}} - \frac{e^{-\frac{1}{\alpha_a}}}{1 - e^{-\frac{1}{\alpha_a}}}\right) T_a D}$$

Fig 4b Heat exchanger transfer function (low frequency approximation)

seems to indicate an inaccurate representation, for, with the nominal phase lag from the dead time part of the plot, the total phase is considerably in excess of the test value. However, this is certainly an error on the conservative side. The "T" for the second-order term is related to the transit time of a particle of water through the exchanger tubes; it is not arbitrarily selected as the number that puts the hump in the right place.

All of these curves in Fig 3 do represent (with varying degrees of accuracy) what the exchanger does in actual operation — any of the curves are probably accurate enough for ordinary prediction of controller settings and performance.

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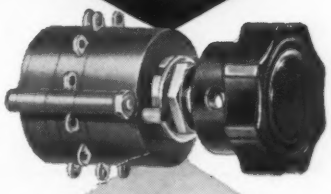

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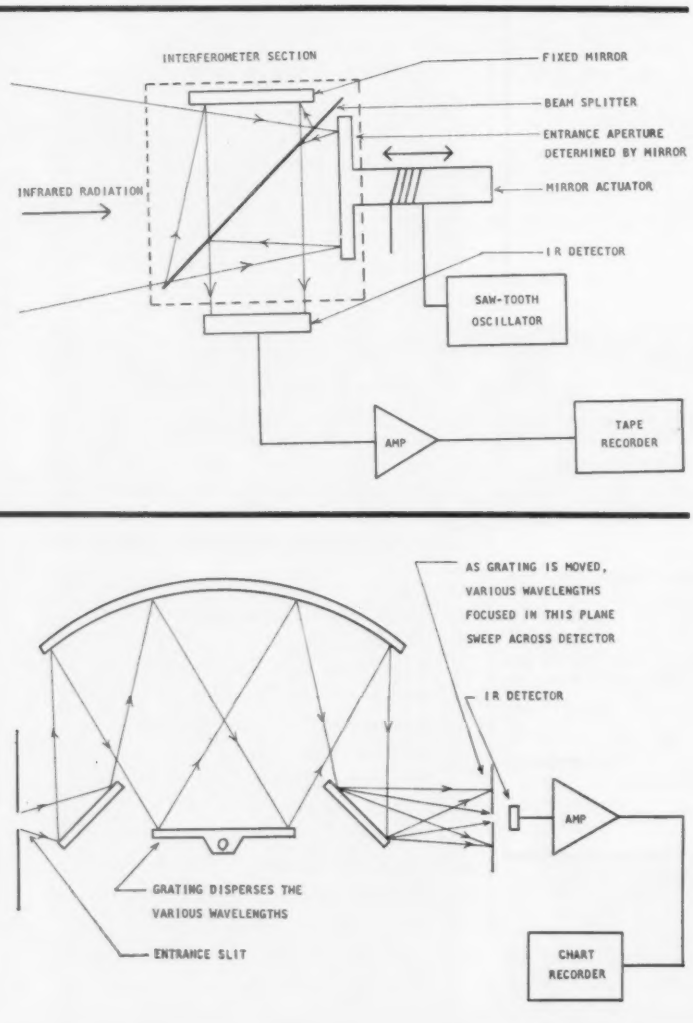

Fig 1 Comparison of interferometer-spectrometer (top) and a conventional rocking grating IR spectrometer (bottom).

Although infrared spectroscopy has developed into one of the most powerful analytical tools available today, its use has often been limited by inadequate sensitivity. It has been difficult and frequently impossible to obtain data on weak sources of radiation. To overcome this, as well as other limitations and thereby extend the application of IR spectroscopy, Block Associates, Inc., Cambridge, Mass. under partial sponsorship of the Geophysics Resch. Directorate of AF Cambridge Resch. Labs., has developed an interferometer spectrometer which basically attains the advantage of increased sensitivity by, first, making more efficient use of the measuring time – examining all wavelengths simultaneously instead of one at a time as in a conventional spectrometer – and second, by not requiring a narrow entrance slit. These factors, reports Block Associates, enable the unit to accept more radiant energy from the source.

PRINCIPLE OF OPERATION

As an introduction to the operating principle of Block Associates' new spectrometer, consider an acoustical analogy. One way to analyze sound is to pick it up by a microphone, then record the output from the amplifier on tape. Then play the tape through a wave analyzer which records the amplitude of each frequency component in the sound. This same procedure could be used to analyze infrared or other electromagnetic radiation if detectors were available that were fast enough to follow the fluctuations of the electromagnetic waves.

Since detectors are not fast enough, it is necessary to slow down the waves in order to use this method. Block does this by making use of an interferometer. The process of slowing down the waves can be visualized as being similar to obtaining slow motion in a movie projector. The interferometer can be considered to make a picture of the wave trains of light. This picture is the fringe pattern produced by the interferometer. When one of the mirrors in the interferometer is moved back and forth at a slow, constant velocity, the "camera" becomes a movie projector; the "picture" moves. The motion is manifested as an alternate brightening and darkening of the central fringe. An infrared detector, placed at the central fringe, converts the alternate brightening and darkening into an alternating electrical signal. If the mirror velocity is kept constant at a predetermined value, the frequency of the ac signal is directly related to the wavelength of incident radiation,

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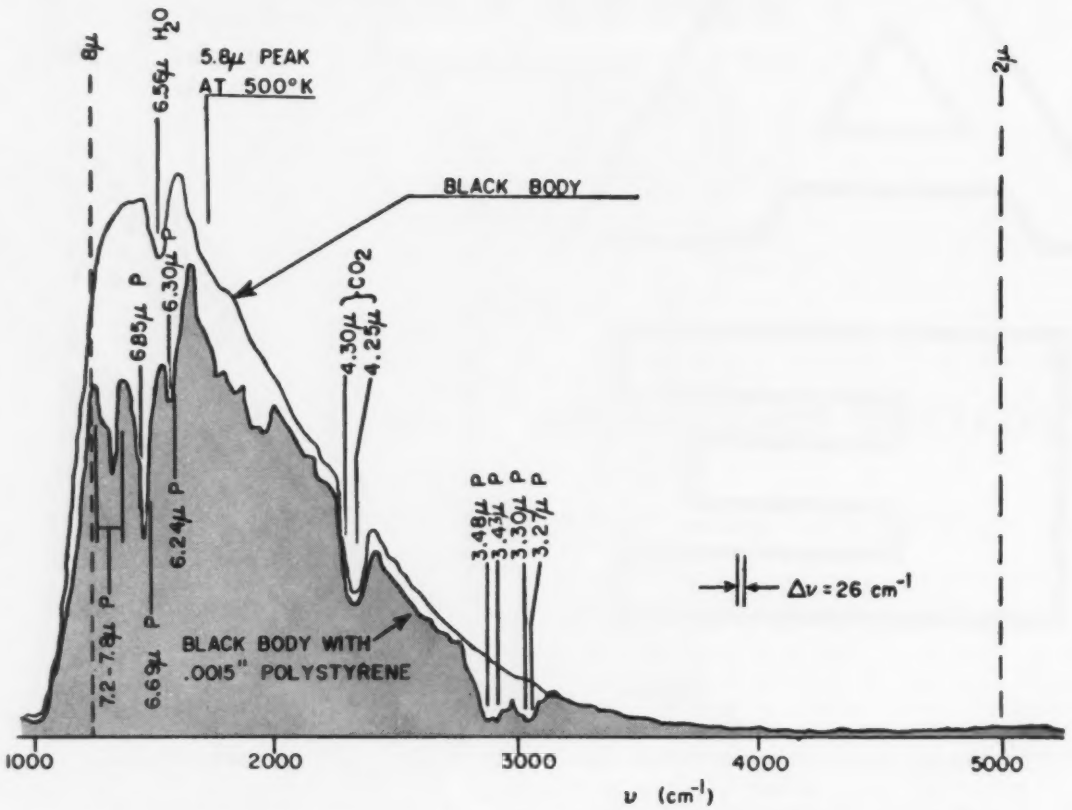

Fig 2 Comparative interferometer-spectrometer emission spectra of black body and black body with 0.0015" polystyrene showing absorption of the atmosphere and polystyrene. The above spectrum was obtained with a 14S interferometer-spectrometer under the following conditions: Bolometer detector; 1cm aperture, CaF2 optics; 4° field of view; 500° K black body source; 6 seconds recording time at 2 scans per second ≈ 30 cm^{-1} resolution.

assuming for the moment that the incident radiation is at one given wavelength. If incident radiation containing many wavelengths were introduced into the system, the output of the detector would consist of a superposition of all the ac signals corresponding to all the wavelengths in the source. This superposition is the same thing that happens in the analogous microphones when the incident sound consists of many notes.

Electrical outputs of the microphone system and the interferometer-detector system are equivalent. Consequently, the same procedure of using tape recording and playing it back through an audio wave analyzer permits the infrared spectrum to be recovered just as the acoustic spectrum is recovered. Mathematically, one can consider that the interferometer takes the Fourier transform of the incident radiation, and the wave analyzer takes the inverse transform.

DATA REDUCTION

Use of a tape recorder and wave analyzer combination, according to Block Associates, is the simplest way to convert the superposed frequencies, called an interferogram, back into the original spectrum. Paper feed of a chart recorder is mechanically linked to the frequency tuning control of the wave analyzer, so as the paper slowly advances, the frequency is changed. This produces a spectrum which has as its abscissa a scale which is linear with frequency (or wavenumber).

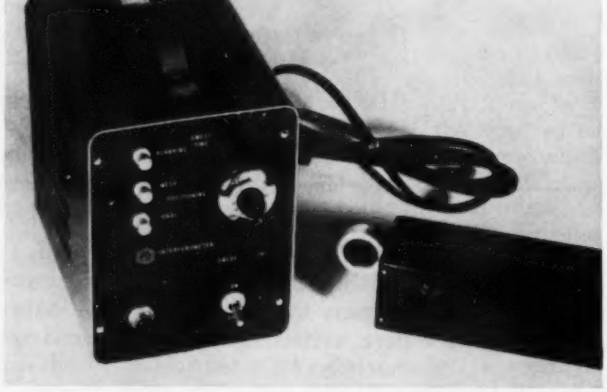

Fig 3 Complete commercial version of Block Associates' Interferometer-Spectrometer. Available with a choice of infrared detectors, the instrument is composed of an optical head which measures 2½ x 2½ x 8 inches and a separate electronics package measuring 6 x 8 x 10 inches. Price of the complete instrument depends on detectors, but is approximately $4500.

Data reduction is not limited only to the use of the above procedure. If desired, the interferogram can be converted into digits and the inverse transform can be calculated on a computer.

Because each wavelength of the source appears as a

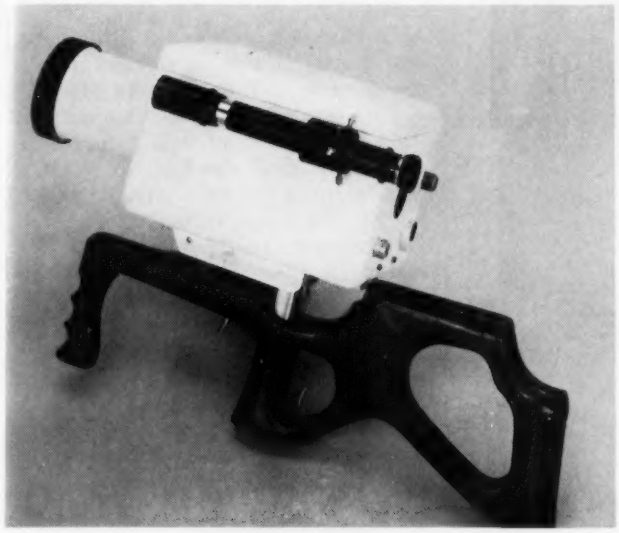

Fig 4 Hand-held field model of Block Associates' Interferometer-Spectrometer.

different electrical frequency, several additional methods of data display can be used. If a spectrum is desired without going through the delay of tape recording and wave analysis or computer programming, the output of the spectrometer can be fed directly into a panoramic wave analyzer. If one is interested in only a few wavelengths, several tunable narrow bandpass filters can be placed in the output.

Block Associates described the large gain in sensitivity as the most striking advantage of interference spectroscopy, attributing this gain to the following two factors:

- The interferometer has a much larger entrance aperture (determined by the mirror size), whereas conventional instruments are limited by slits. Essentially, the product, (entrance angle) x (area), which one can call the throughput, is much higher in an interferometer. For typical instruments, this can be a factor of 100 greater than in a conventional spectrometer.
- The interferometer spectrometer examines each wavelength throughout the entire time period of each scan. In a conventional instrument, each wavelength is only examined for a very short part of the scan time $-1/n$ times the scan time if n is the number of resolution elements. A basic theorem of information theory shows that signal-to-noise increases as the square root of the measuring time, hence, an interferometer achieves a gain which is the square root of n for the same scan time. For typical instruments this can be a factor of 50. Note that this gain is realized even when examining point sources where the throughput gain is not large.

The price one has to pay for these gains is dependent on the data reduction method. If the tape loop and wave analyzer are used, it is necessary to wait until the wave analyzer has been tuned through the entire range of frequencies which correspond to the spectral region of interest. Here, one must pay for the gain with a time delay in the order of fifteen minutes. If a panoramic wave analyzer is used, the presentation is immediate, but the resolution may be limited.

Comparing its interferometer spectrometer with conventional dispersive instruments (prism and grating types), Block Associates believes that its unit offers many advantages. Some of these advantages are: 1,000 to 10,000 times more sensitive when examining extended sources; high reliability due to only one moving element; low power consumption; rapid scan $-$ 4 spectra/second with present model.

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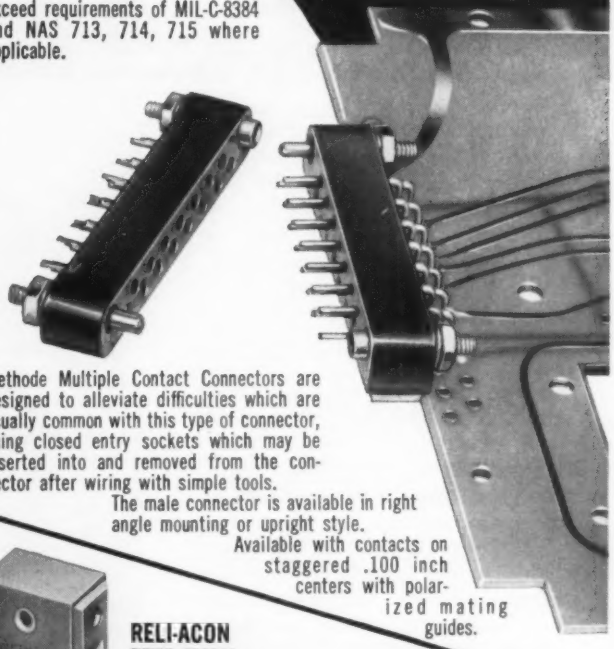
Methode Multiple Contact Connectors

Designed for aircraft, radar, and missile applications. Especially suitable for use with printed circuit boards or, Plyo-Duct, Methode's flat multi-conductor cabling.

TWO PART PRINTED CIRCUIT CONNECTOR
Series MD-1100 and SD-1100.
Exceed requirements of MIL-C-8384 and NAS 713, 714, 715 where applicable.



Methode Multiple Contact Connectors are designed to alleviate difficulties which are usually common with this type of connector, using closed entry sockets which may be inserted into and removed from the connector after wiring with simple tools.
The male connector is available in right angle mounting or upright style.
Available with contacts on staggered .100 inch centers with polarized mating guides.

RELI-ACON FEED-THRU STYLE CONNECTOR Series FTD 1500
These connectors employ a tri-furcated contact which withstands extreme vibration. Presently available in 15 contacts on .100 inch centers for a nominal card opening of .062 inch. Moisture seal is available about the board or cable entrance.

Flexible multi-conductor wiring is available in standard sizes from stock or custom patterned to your specifications.

COMPLETE information and data are available on both of above connector types . . . write today.

Methode manufacturing corp.
7447 W. Wilson Ave
Chicago 31, Ill.

CIRCLE NO. 20 ON INQUIRY CARD

VIBRATION AND SHOCK MOUNTS

Knitted Stainless-Steel Wire Cushions Provide Non-linear Spring Characteristics and Excellent Damping

Requirements for mounting systems to protect equipment against shock and vibration are more demanding now than ever before. Space is often tightly restricted and weight usually must be kept to a minimum. The resilient elements in the mounting system must provide excellent damping characteristics and respond quickly and precisely to sudden increases in pressure and overloading. Extremes of temperature and atmospheric conditions must be anticipated. Shelf life of the control element must be long and the element must not deteriorate with age on installation. In service, the element is required to resist fatigue failure and to deliver reasonably long effective life.

A type of vibration isolation that appears to fulfill these performance requirements over a wide range of vibratory frequencies is a recent development made of stainless steel. Termed Met-L-Flex, the element comprises a knitted stainless steel wire cushion

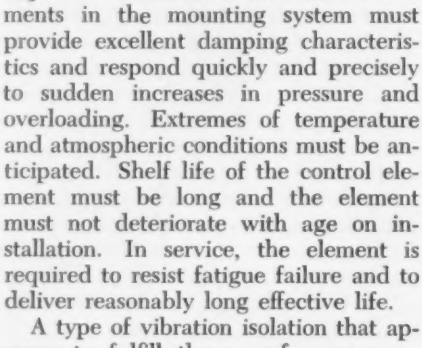


Fig 1 Load vs deflection curve for a stainless-steel wire mesh vibration isolator shows the non-linear characteristics of the design.

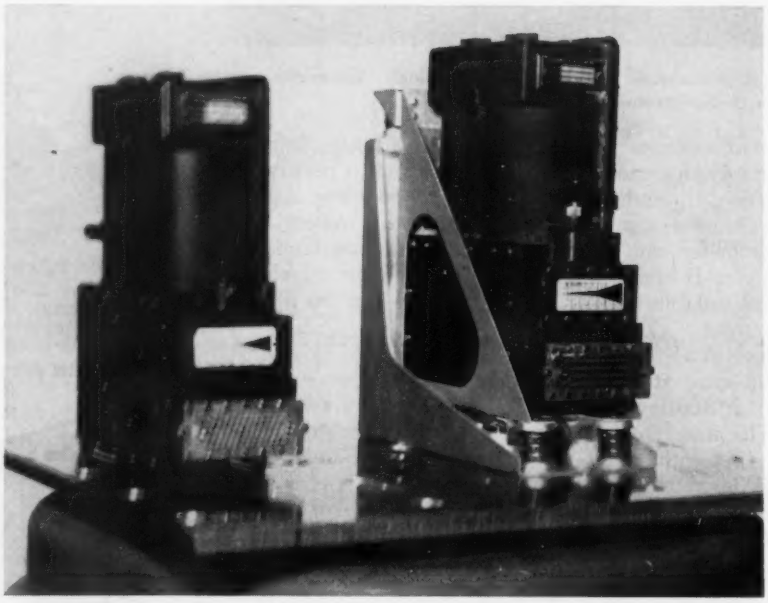


Fig 2 Vibration testing visually demonstrates dampening influence of stainless steel cushions. Vibratory input by electromagnetic shake table is about .187 inches at 35 cycles per second, equalling a 12 g acceleration force. Equipment at left is bolted to test table; that at right is mounted on stainless cushions. Clear image of measuring arrow (on white panel) at right shows no perceptible motion. Calculations show, in this instance, an isolation efficiency exceeding 95 percent.

housed within a compression spring. The concept originated with Robinson Technical Products Inc., Teterboro, New Jersey.

The cushioning element is a knitted stainless steel mesh structure with interlocking spring-like loops. Multi-directioned orientation of the loops allows precise control of compressibility and resiliency. Housed in a stainless steel mounting structure designed for the particular end use, the cushion possesses characteristics similar to a spring and dash-pot. Stress on individual spring loops falls well below fatigue limits, giving the element a long effective life even under periodic shock loading.

Versatility and precision of stainless steel cushioned mounts are illustrated by the following examples. Low frequency systems for protection of electronic equipment on jet aircraft have been engineered using stainless steel elements that pass natural frequencies of 6 to 9 cycles per second, yet with an isolation efficiency approaching 90 per cent at 30 cps. High frequency mounts for aircraft lights incorporate stainless steel elements with natural frequencies of 80 to 90 cps that achieve 90 percent isolation of frequencies in the 300 to 600 cps range. A stainless steel mount for military communication equipment has been developed with a load range down to three pounds. Another design for a machine tool mount employs the stainless steel cushion to handle loads up to 10,000 pounds. This last represents vibration control under static pressures exceeding 50,000 pounds per square inch.

One of the major advantages of stainless steel as a vibration isolation material is its effective service life. Metal

vibration isolators are generally considered best for stability in storage and long life in service. Yet even metals have limitations: corrosion and fatigue failure often limit life.

Many metals possess sufficiently high ultimate strength to be virtually free of fatigue failure at correctly designed stress levels. Many others are sufficiently corrosion resistant to be suitable for integration into vibration control systems. But few materials posses the two properties. Among materials offering both, stainless steel is perhaps the lowest priced in terms of amortized cost. Other more costly materials include Monel, and certain proprietary chromium-, chromium-nickel, cobalt- and vandium-bearing alloys.

In addition to corrosion resistance and high fatigue strength several other properties inherent in stainless steel prompted its selection for the cushioning elements. With a damping capacity five times greater than rubber, the corrosion resistant metal diminishes oscillations much more rapidly. Spring loading rates for the stainless steel wire are non-linear; the mount in compression increases in stiffness as pressure is applied (see Fig 1). These non-linear characteristics of the design provide (1) greater stability, (2) resistance to bottoming-out during over-load conditions, (3) greater shock protection, (4) greater absorption of energy during the work cycle, and (5) negligible drift rate.

Resistance to environmental extremes is another reason for selection of stainless steel. It is virtually impervious to the effects of sunlight, oil, water, fungi, ozone, dust, and most chemicals and solvents. Over a 500 degree temperature range, between minus 130°F and plus 375°F, the stainless steel woven control element is unaffected. Abrupt changes in atmospheric conditions similarly fail to affect the element.

Three types of stainless steel mounting systems have been developed to combat severe vibration and shock. Within certain limits of equipment dimensions and inertia characteristics, conventional base mountings may prove adequate. Such a mounting will incorporate several of the stainless steel cushioning elements shown in Fig 2 to limit radial or negative motion, to absorb shock, and to provide load tolerance and vibration dampening. If equipment cannot be mounted on a conventional base, an effective center-of-gravity type system may provide the answer. A third possible configuration can be constructed in which resilient mountings of stainless steel lie both in the plane of the center of gravity, and at distances from it equal to the radii of gyration about the principal axis.

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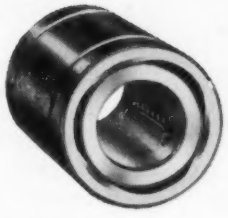
CIRCLE NO. 21 ON INQUIRY CARD →

...*for* **MINIATURIZATION**



LOW FRICTION and WEAR
LASTING PRECISION ALIGNMENT
ELIMINATE BINDING and CHATTER
ZERO SHAKE or PLAY
LONG LIFE — LOW MAINTENANCE
SOLVES SLIDING LUBRICATION PROBLEMS

Used by progressive engineers in the latest guidance, fire control and navigation systems, computers, inertial devices, instruments.

Various types of* BALL BUSHINGS *are made for shaft sizes from* 1/8" *to* 4"... *with small sizes available in Stainless Steel. Write for literature and name of our representative in your city.

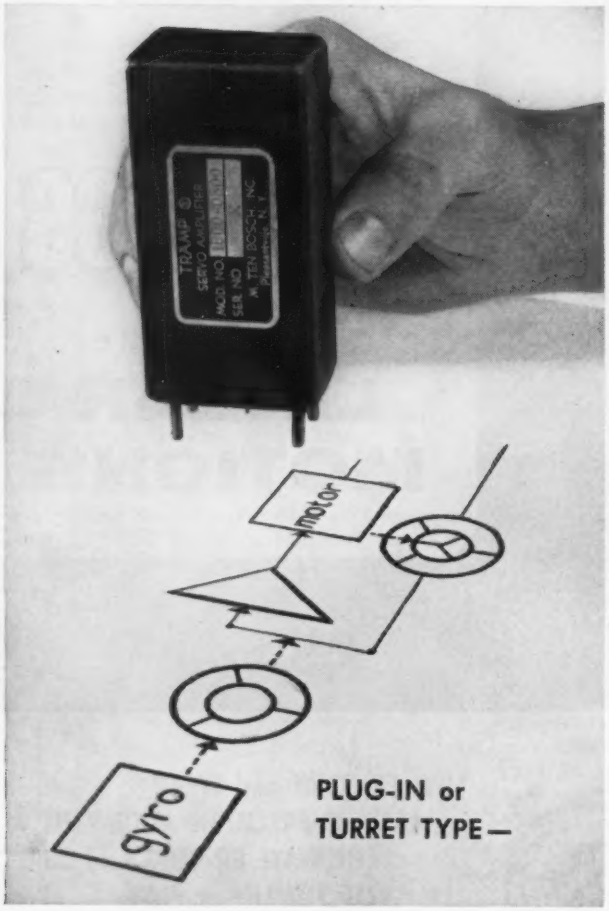
THOMSON INDUSTRIES, Inc.

Dept. A, MANHASSET, NEW YORK

Electronic Building Blocks
Series 1-TRAMP

Tramp®

will solve your servo amplifier problems just as easily



A transistorized building block that gives the design engineer—
- more than 1 watt controlled power per ounce
- voltage gains up to 30,000
- 10,000 hours of operation

Can be used in—
- differential DC applications
- magnetic amplifier applications
- relay applications

Hermetically sealed, meets government environment specs.

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CIRCLE NO. 22 ON INQUIRY CARD

MACHINE PISTON RODS

Tenfold Increase in Life of Working Parts

Combination of a new rod material called Bronze Case together with hardened steel bushings gives Thomson Industries Inc., Manhasset, N. Y., greatly improved performance in their piston and guide rods and similar linear applications. Bronze bearings material is put on the large area within a bushing, thus providing substantial reductions in the cost of bushing and rod replacements. The cost of lubrication is reduced as well as the size and weight of many mechanisms. Using Bronze Case rods and hardened steel bushings also increases operating efficiency and frequently eliminates stick-slip and chatter. The new combination also eliminates rust and nick problems.

High quality bearing bronze is fused on the surface of a steel rod which is subsequently ground and straightened to very close tolerances. The bronze fusing is done by a high temperature spraying operation which forms a coating of controlled porosity for lubricant retention. Lubricants don't wipe off and amount stored is enormous since it is stored all over the relatively large shaft surface.

In conventional reciprocating applications, all of the wear is concentrated on the short length of bearing material within the support bushings. With Bronze Case, the effective bearing length is increased by the length of stroke and therefore the wear is greatly reduced as it is spread over such a large area. Actually the increase in life of the parts is usually more than the ratio of length of stroke divided by the bushing length because of better lubrication. Figure shows savings which can be made by reductions in replacements and machine downtime.

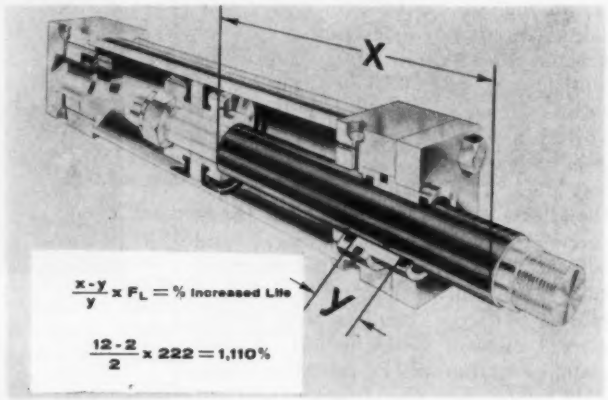
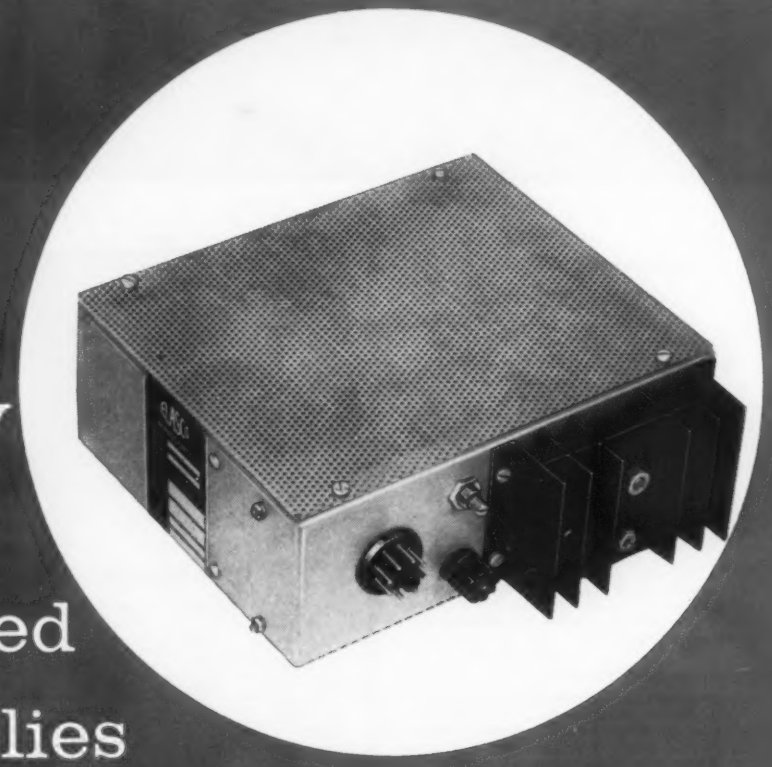


Fig 1 In the formula, $(x-y)/y$ times $F_L = \%$ Increased Life, "x-y" is length of stroke, "y" is the bushing length and "F_L" is a lubrication factor. The latter is the added improvement with Bronze Case rods due to much greater lubricant storage and the fact that the porous surface holds it in proper position along the stroke length. Oil or grease do not get pushed to the end of the stroke. Comparative tests have shown that the F_L factor is a function of the frequency and amount of lubrication applied to the respective shaft surfaces. In applications providing very frequent copious lubrication, the F_L factor can go as low as 100 which means no added improvement over that gained by the $(x-y)/y$ ratio. In the case of infrequent lubrication, tests indicate an F_L factor of 444. In this example given for the piston rod, an F_L factor of 222 was used which assumes periodic lubrication under average conditions. In this application life is increased over tenfold.

Bronze Case rods made of AISI 1060 steel, heat treated to 213,000 psi, are available from Thomson Industries. This greater strength affords savings in cost, weight and space in many new designs, by use of smaller rods and bushings. In some applications, the greater operating efficiency permits the use of smaller motors and drives.

Write No. 258 in Box on Inquiry Card

A New Family of Transistorized Power Supplies



HIGH RELIABILITY IN A 2 AMP PACKAGE

FLEXIBILITY, PERFORMANCE QUALITY, AND VALUE

Elasco power supplies are of modular construction and lend themselves to inclusion in proprietory products and test installations. Two SV-2A units may be mounted side by side on a 3½" x 19" rack panel, or mounted as a subassembly on either the 8½" x 8⅜" or the 8½" x 3" face.

Manufactured in accordance with the highest commercial standards and using high quality materials and components, Minisource® power supplies deliver value and reliability. Quality control is rigorous and each supply is performance checked for a minimum of 24 hours prior to shipment.

Military power supplies and modifications to standard models are made to customer specifications. *Send us your requirements.*

SV-2A MINISOURCE® SERIES SPECIFICATIONS

INPUT VOLTAGE: 105 to 125 volts

INPUT FREQUENCY: 60 to 400 cps

MODEL	VOLTS	CURRENT
SV6-2A	6	0-2A
SV12-2A	12	0-2A
SV18-2A	18	0-2A
SV24-2A	24	0-2A
SV28-2A	28	0-2A

Each variable to ±1 volt

LINE REGULATION: 5 millivolts

LOAD REGULATION: 30 millivolts max.

RIPPLE: 5 millivolts peak to peak

RESPONSE TIME: 50 microseconds or less . . . no load to full load

OPERATING TEMPERATURE: 0 to +50°C

DIMENSIONS: 8½" x 8⅜" x 3" high

ELASCO INCORPORATED
FIVE PRESCOTT STREET
ROXBURY 19, MASSACHUSETTS
HIghlands 2-1600

CIRCLE NO. 23 ON INQUIRY CARD

STANDARD AND SPECIAL PURPOSE POWER SUPPLIES FOR

control systems, transistor powering, computer systems, test equipment, guided missile circuits, aircraft electronics, telemetry circuits, DC filament supplies, magnetic amplifier references, bias sources

TRANSISTORIZED AC TO DC ELASCO MINISOURCE® POWER SUPPLIES

FIXED AND SEMI-VARIABLE

TRANSISTORIZED
Higher current capabilities in a smaller lighter package . . . greatly improved efficiences and reliability . . . less heat per watt input . . . no filament power losses . . . reduced transformer and rectifier losses . . . no warmup time . . . longer life.

COMPLETE SERVICEABILITY
All components accessible for checking and replacement . . . potting has been eliminated and a printed circuit board incorporated for compact packaging.

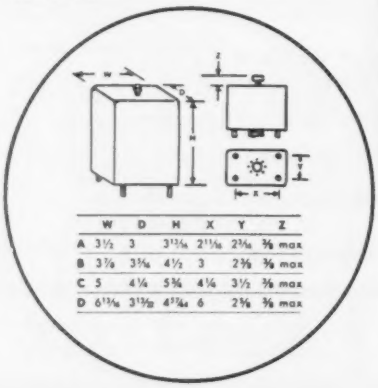
EFFICIENT HEAT TRANSFER
Accomplished by mounting the power transistor on the geometric center of the black anodized aluminum housing, which becomes an efficient black body radiating heat sink . . . Better heat transfer assures more accurate, stable and long-life performance of all components.

FULL PROTECTION
Fusing in the collector of the power transistor protects the supply without affecting regulation.

All standard Minisource® power supplies are furnished with an octal glass to metal header (other terminations available upon request) and packaged in a black anodized aluminum transformer case. There is no extra charge for 400 cycles.

SPECIFICATIONS
VOLTAGE REGULATED — FIXED OR SEMI-VARIABLE * OUTPUT

Input Frequency: 60 cps or 400 cps
Input Voltage: 105-125 VAC
Output Voltage: 4 to 200 VDC
Output Current: 50 to 500 ma
Regulation: Better than 0.5%
Ripple: Less than 0.25%
Polarity: May be used Floating, Positive, or Negative
*Screw driver adjustment on top of semi-variable units.



	W	D	H	X	Y	Z
A	3 1/2	3	3 13/16	2 11/16	2 5/16	3/8 max
B	3 1/8	3 5/16	4 1/2	3	2 5/8	3/8 max
C	5	4 1/4	5 3/16	4 1/16	3 1/2	3/8 max
D	6 13/16	3 13/16	4 13/16	6	2 5/8	3/8 max

FIXED MINISOURCE

MODEL	VOLTAGE	CURRENT	CASE SIZE
M4.5-50	4.5v.	50 ma	B
M4.5-100	4.5v.	100 ma	B
M4.5-250	4.5v.	250 ma	B
M4.5-500	4.5v.	500 ma	B
M6-50	6v.	50 ma	A
M6-100	6v.	100 ma	A
M6-250	6v.	250 ma	A
M6-500	6v.	500 ma	B
M12-50	12v.	50 ma	A
M12-100	12v.	100 ma	A
M12-250	12v.	250 ma	B
M12-500	12v.	500 ma	B
M22-50	22v.	50 ma	A
M22-100	22v.	100 ma	B
M22-250	22v.	250 ma	B
M22-500	22v.	500 ma	B
M25-50	25v.	50 ma	B
M25-100	25v.	100 ma	B
M25-250	25v.	250 ma	B
M25-500	25v.	500 ma	B
M28-50	28v.	50 ma	B
M28-100	28v.	100 ma	B
M28-250	28v.	250 ma	B
M28-500	28v.	500 ma	B
M30-50	30v.	50 ma	B
M30-100	30v.	100 ma	B
M30-250	30v.	250 ma	B
M30-400	30v.	400 ma	B
M50-50	50v.	50 ma	B
M50-100	50v.	100 ma	B
M50-250	50v.	250 ma	C
M100-100	100v.	100 ma	C
M150-100	150v.	100 ma	C
M200-100	200v.	100 ma	C

SEMI-VARIABLE MINISOURCE

MODEL	VOLTAGE	CURRENT	CASE SIZE
V4-50	3-6v.	50 ma	B
V4-100	3-6v.	100 ma	B
V4-250	3-6v.	250 ma	B
V4-500	3-6v.	500 ma	B
V8-50	5-10v.	50 ma	A
V8-100	5-10v.	100 ma	A
V8-250	5-10v.	250 ma	B
V8-500	5-10v.	500 ma	B
V12-500	10-15v.	500 ma	B
V15-500	10-20v.	500 ma	A
V15-100	10-20v.	100 ma	B
V15-250	10-20v.	250 ma	B
V18-500	15-20v.	500 ma	B
V22-500	20-25v.	500 ma	B
V25-50	20-30v.	50 ma	A
V25-100	20-30v.	100 ma	B
V25-250	20-30v.	250 ma	B
V28-500	25-30v.	500 ma	B
V32-250	30-35v.	250 ma	B
V35-50	30-40v.	50 ma	B
V35-100	30-40v.	100 ma	B
V38-250	35-40v.	250 ma	B
V42-250	40-45v.	250 ma	C
V45-50	40-50v.	50 ma	B
V45-100	40-50v.	100 ma	B
V48-25	45-50v.	25 ma	C
V65-50	60-70v.	50 ma	B
V65-100	60-70v.	100 ma	B
V75-50	70-80v.	50 ma	B
V75-100	70-80v.	100 ma	B

ELASCO can package power supplies in any way the customer may desire (within reason), and to comply with military requirements.

ELASCO inc.

FIVE PRESCOTT STREET, ROXBURY 19, MASSACHUSETTS
Telephone: HIghlands 2-1600

IF THE SUPPLY YOU REQUIRE IS NOT LISTED ABOVE, ELASCO WILL BE HAPPY TO BUILD A MINISOURCE® TO YOUR SPECIFICATIONS.

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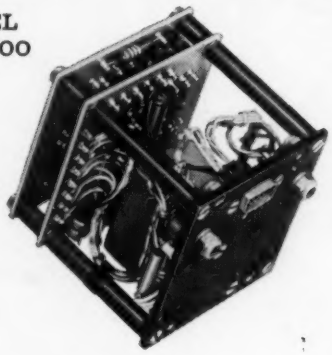
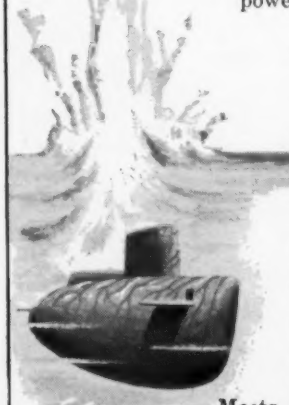
We welcome modifications to our standard Power Supply Line!

MODEL 2E30-100



military requirement

Polaris missile submarines are using this power supply in the precision servo system which drives and positions the navigational periscope. Developed by Nortronics, Norwood, Massachusetts, the system has proven very successful. The critical accuracy necessary for navigation required a very stable power supply.

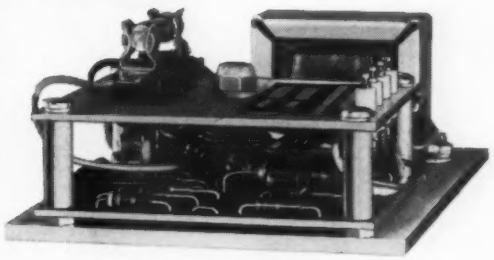


Input:
115 volts ±10% 400 cps ±5%
Dual Output:
#1 +30 volts D.C. @ 100 ma
#2 −30 volts D.C. @ 100 ma
Line Regulation:
.05% for 105 to 125 volts input
Load Regulation:
.1% for 0 to full load
Ripple:
.1% peak to peak
Operating Temperature:
0 to +50°C
Storage Temperature:
−65 to +85°C
Dimensions:
3" x 2⅞" x 3⅜" high
Weight: 1#

Meets MIL-E-16400b (USN)
MIL-STD-242

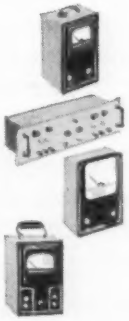
Modification of standard Minisource® Model M30-100

MODEL SM5-15



commercial application

A complete family of temperature indicating instruments and bridges, manufactured by RdF Corporation (formerly Arthur C. Ruge Associates) Hudson, New Hampshire, utilizes the SM5-15. Small and light enough to go into portable instruments with output measurements to within 2.5°F, it is precise and well regulated for use in a high accuracy temperature averaging wind tunnel system with output measurements to .1°F.



Input:
115 volts ±10% 60 to 400 cps.
Output:
+5 volts D.C. @ 15 ma
Line Regulation:
.1% for 105 to 125 volts input
Load Regulation:
.25% for 0 to full load
Ripple:
.1% peak to peak
Operating Temperature:
0 to +50°C
Storage Temperature:
−40 to +75°C
Dimensions:
5" x 3½" x 1½" deep
Weight: ¾#

Modification of standard Minisource® Model M5-50

These are typical examples of Elasco's flexibility in modifying the standard Minisource® line to customer requirements.

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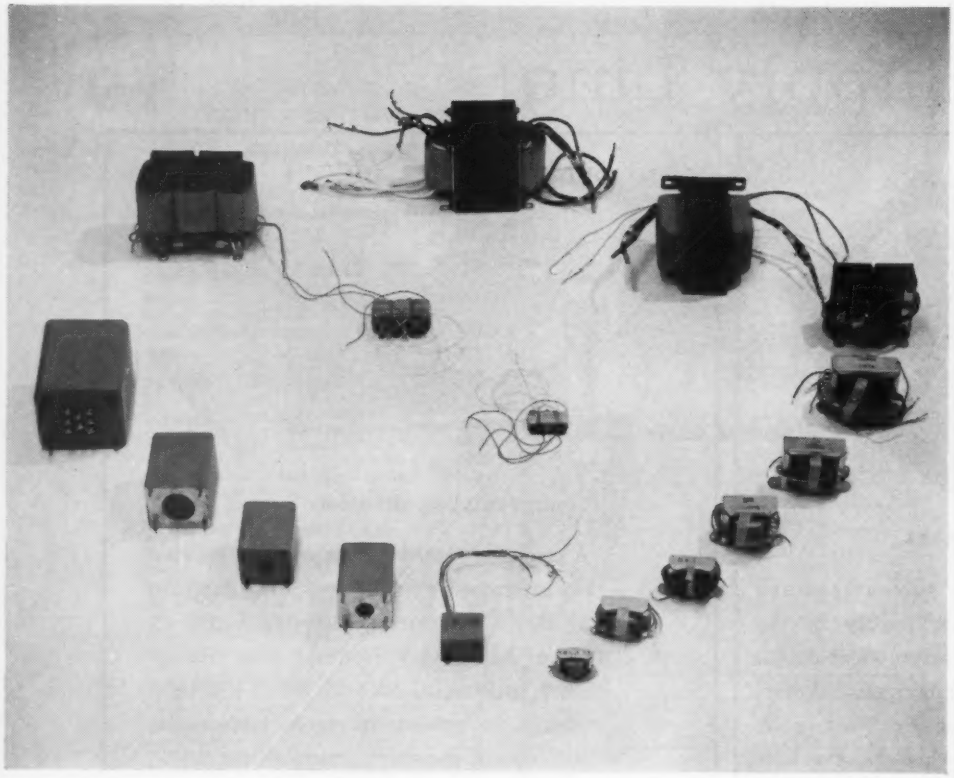
CIRCLE NO. 25 ON INQUIRY CARD

MAGNETIC COMPONENTS



COMMERCIAL AND MIL-T-27 A GRADES

- POWER TRANSFORMERS
- INDUCTORS
- SATURABLE REACTORS
- REGULATING MAGNETIC AMPLIFIERS
- AUDIO TRANSFORMERS
- PULSE TRANSFORMERS
- CHARGING REACTORS
- TRANSISTOR TRANSFORMERS
- STATIC CONVERTERS

PROTOTYPES AND SPECIALS IN A HURRY!

Elasco set up facilities for the manufacture of magnetic components to be used in Minisource® power supplies 3 years ago. Difficulty in finding a vendor that would consistently provide fast delivery, reasonable price, and constant quality and performance necessitated our action.

With a staff of experienced magnetics engineers, seasoned production personnel, and established manufacturing techniques, our magnetic components facility has grown into a complete operating division.

The Elasco Magnetic Components Division is now prepared to design and manufacture the components listed to your specifications and requirements.

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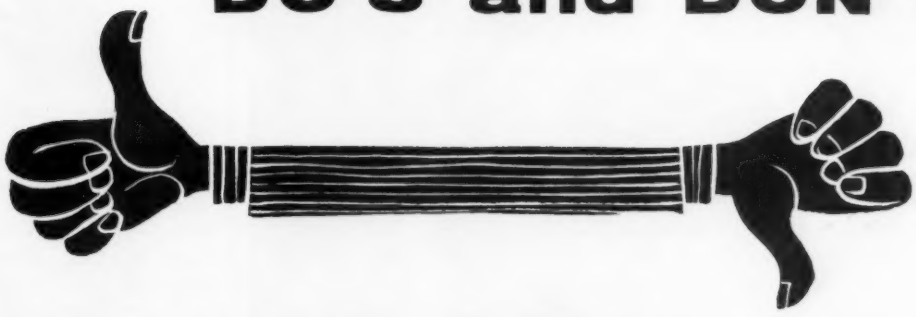
MANUFACTURERS OF MINISOURCE® POWER SUPPLIES • CONTRACT MANUFACTURERS

CIRCLE NO. 26 ON INQUIRY CARD

DO'S and DON'TS



for Precision Pots

As Prepared By The Precision Potentiometer Manufacturers' Association

If you are a manufacturer or user of precision pots, or a supplier to the Industry, you will be interested in activities of the Precision Potentiometer Manufacturers' Association established to carry out four major objectives.

1. To encourage voluntary standardization to further product reliability.

2. To accelerate the growth of the technology.

3. To expand the markets for precision potentiometers.

4. To represent the industry to the Government and users.

Among the programs to accomplish these objectives is that of the Reliability and Applications Committee recently approved at the first annual meeting of the Association. A major part of this Program, announced by Chairman Hollis Grey, of Technology Instruments Corp., will be to educate users to the best practices in purchasing and using precision pots. As one means to this end he proposed development of a check list of design tips for pot users based on suggestions from all member manufacturers. Here is the final draft of the check list passed by the Association Board of Directors at their March 1961 Meeting.

1. DO realize that the precision potentiometer is a precision instrument, manufactured to close electrical and mechanical tolerances. While they can withstand the shock and vibration of the severest aircraft and missile environment, they must be handled with care and the respect accorded a high-precision instrument.

2. DO NOT hammer on the shaft.

3. DO make certain when pressing gears, knobs, et cetera, on the shaft, that the load is carried by the opposite end of the shaft, not the bearings or the internal mechanism of the pot.

4. DO make certain when drilling holes to support the shaft in a V block and to protect the bearings from chips and foreign matter.

5. DON'T saw off shaft extensions or add screw driver slots — sawing causes vibration and other internal and external loads that nearly always damage the potentiometer.

6. DON'T, when removing gears from the pot shaft, apply excessive end load to the bearings or the internal mechanism of the pot.

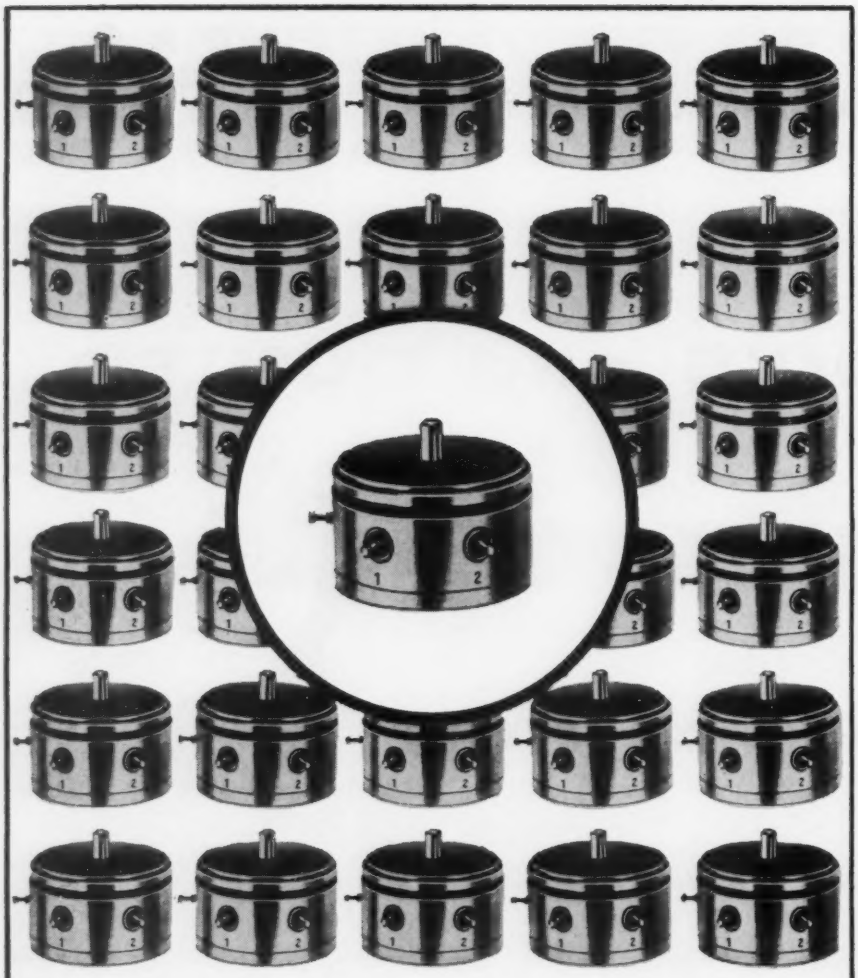
7. DO call for a flat or undercut on shaft when using set screws, since set screws will permanently damage shafts.

8. DON'T, under any circumstances, hammer on the rear of the pot to force it into a mounting register.

9. DO use servo mount ball-bearing pots in the following applications:

A. Motor-driven gear train actuated

B. When end or side loads of significant magnitude are expected



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Here is a new addition to MECHATROL'S product line of precision rotating components . . . . . METAL FILM POTENTIOMETERS.

Using a unique new process, MECHATROL manufactures the deposited film potentiometer resistance element in a high vacuum chamber using electron bombardment techniques. This provides a thin film metallic resistance element of extremely fine granularity capable of being resolved into infinitely small changes in resistance. Resolution is better than .005%.

MECHATROL'S thin film potentiometer exhibits superior wear and rotational life under conditions of high ambient temperature and severe vibration and shock. Standard units measure 1-1/16 inches in diameter and are available for servo or panel mounted applications. Special units designed and manufactured to meet your exact specification.

FEATURES:

Resolution . . Better than .005%
Temperature . —55°C to +125°C
Vibration . . . 10 g's, 10-2000 cps.
Rotational Life . . 2,000,000 cycles @ 40 RPM

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CIRCLE NO. 27 ON INQUIRY CARD

COMPONENTS DIGEST

C. Where speed of operation is high

10. DON'T subject pots to rough handling. Pack them separately everywhere — in tote trays, storage bins, packing boxes, etc., to avoid nicking of precision machine surfaces, scratching of protective coatings, bending or breaking of terminals, bending of shafts.

11. DO store them when not in use in sealed containers to protect them from dirt, dust, debris and contamination.

12. DO avoid excessive heat on terminals when soldering leads.

13. DON'T exert extraordinary force twisting or pulling on terminals.

14. DON'T use battery-operated ohmmeters on low-ohms scale to check pots since the current supplied by the ohmmeter can be many orders of magnitude greater than the allowable rating of the pot and consequently burn out end points and taps.

15. DO make certain that the supply voltage to the pot is connected properly — by far the greatest number of open pot windings are caused by the supply voltage being connected between the wiper and one end of the winding, thereby causing sufficient current to be drawn when the pot shaft is rotated to burn out the winding.

16. DO recognize that pot noise, E.N.R., when it does occur, occurs

only when pot wiper is moved and is largely composed of high-frequency energy.

17. DO avoid using pots dynamically as low resistance rheostats in wide-band circuits.

18. DO filter the output of a potentiometer being used dynamically in pulse-triggered circuits (where the high-frequency noise components from the dynamically operated pot can cause false triggering of circuit).

19. DO filter the output of the potentiometer which is dynamically operated through a low-pass filter prior to application as a scope display.

20. DO take care in designing servos to prevent high-frequency, small amp-

litude oscillations (commonly known as dither) of the pot shaft.

21. DON'T use internal stops for stopping servo.

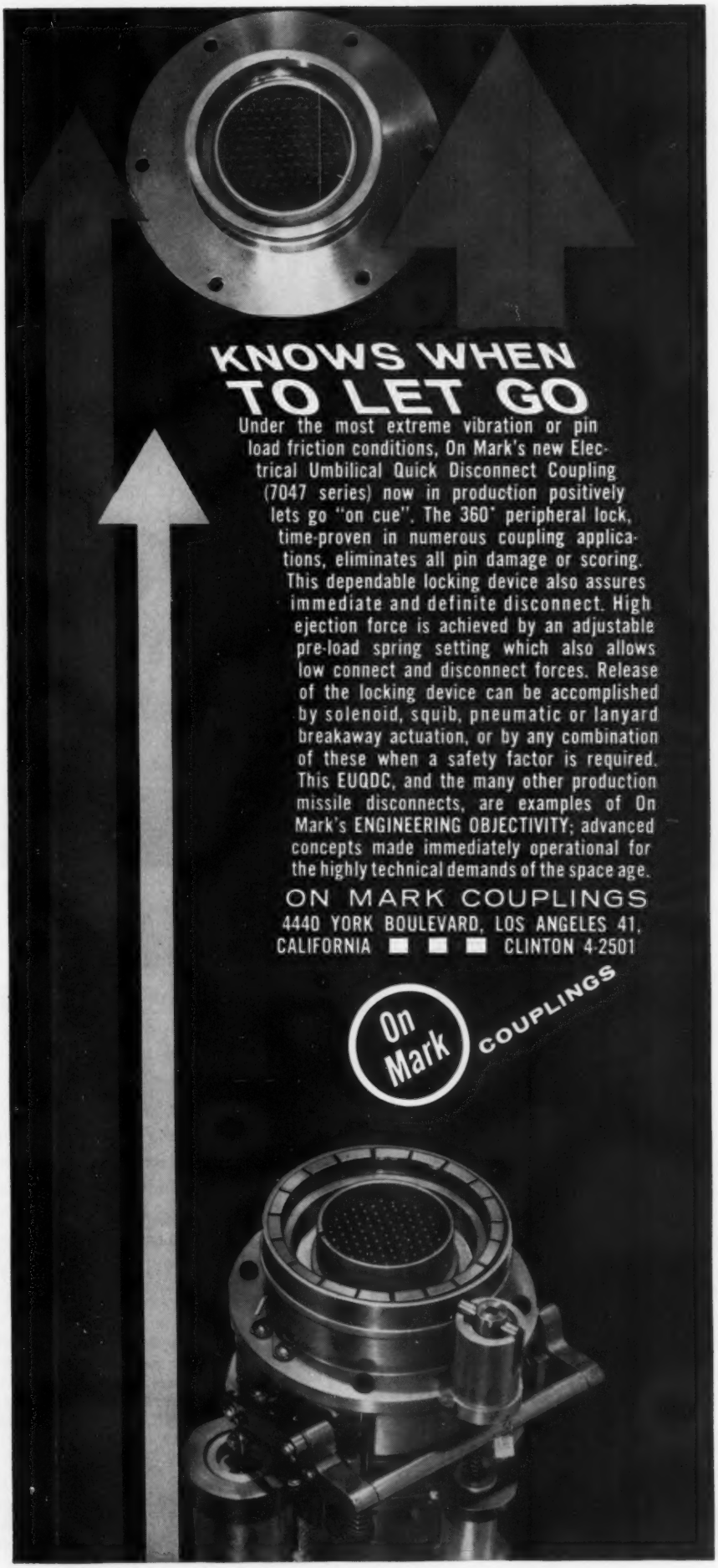
22. DO provide rear support for multi-cup units in high vibration applications.

23. DON'T overspecify environmental conditions, pot accuracy or pot performance with the object of maximizing pot reliability. This may force unneeded design compromises in pot adversely affecting ultimate reliability.

24. DO specify standard types and sizes which have established performance and reliability.

25. DO consult manufacturer, before freezing your design, for help in selecting and specifying a pot of maximum reliability for your application.

• • •


KNOWS WHEN
TO LET GO
Under the most extreme vibration or pin load friction conditions, On Mark's new Electrical Umbilical Quick Disconnect Coupling (7047 series) now in production positively lets go "on cue". The 360° peripheral lock, time-proven in numerous coupling applications, eliminates all pin damage or scoring. This dependable locking device also assures immediate and definite disconnect. High ejection force is achieved by an adjustable pre-load spring setting which also allows low connect and disconnect forces. Release of the locking device can be accomplished by solenoid, squib, pneumatic or lanyard breakaway actuation, or by any combination of these when a safety factor is required. This EUQDC, and the many other production missile disconnects, are examples of On Mark's ENGINEERING OBJECTIVITY; advanced concepts made immediately operational for the highly technical demands of the space age.
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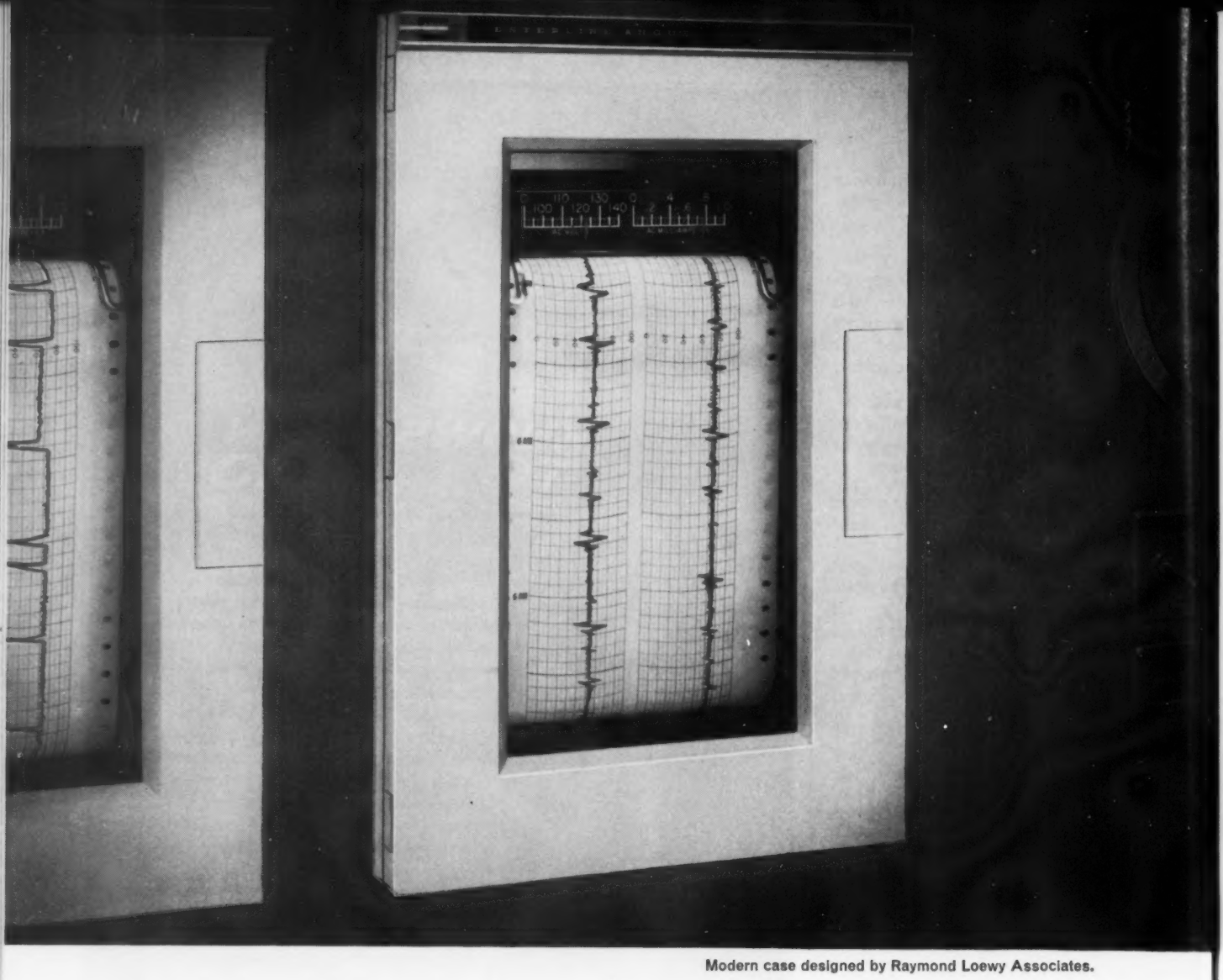


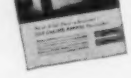
Modern case designed by Raymond Loewy Associates.

New "602" Esterline Angus Two-channel Recorder

This compact two-in-one instrument provides side-by-side synchronized graphs on a single six-inch-wide chart! Use it to check electrical circuits, to determine the quality of arc welds, to indicate proper settings for anodizing, to aid in medical diagnostic research, to provide a wide variety of other vital information. In fact, *any* two variants if expressed as current or voltage can be recorded simultaneously on this new two-pen instrument.

Price? Under $600. That's some $150 less than the cost of two graphic instruments previously required to do the same jobs!

Most important, the Esterline Angus Two-channel Recorder (which carries a unique-in-the-industry two year guarantee) is a product of 50-plus years of experienced craftsmanship—your assurance of dependable, trouble-free performance.



For more detailed information, write for new "602" Recorder descriptive sheet. Address: ESTERLINE ANGUS INSTRUMENT COMPANY, INC., Box 596K, Indianapolis 6, Indiana.

E. G. McDowell, Master Craftsman at Esterline Angus for 48 years.

Excellence in graphic recording for over 50 years—ESTERLINE ANGUS

CIRCLE NO. 29 ON INQUIRY CARD

COMPONENTS 22 DIGEST

INFRARED AND PHOTO DETECTION

A great many articles have been published recently on infrared, but these articles have been concerned mainly with the physics of high frequency radiation and its use in sophisticated military detection systems. This Digest will be concerned with the comparatively simple and inexpensive applications of infrared and photodetectors in commercial and industrial equipment.

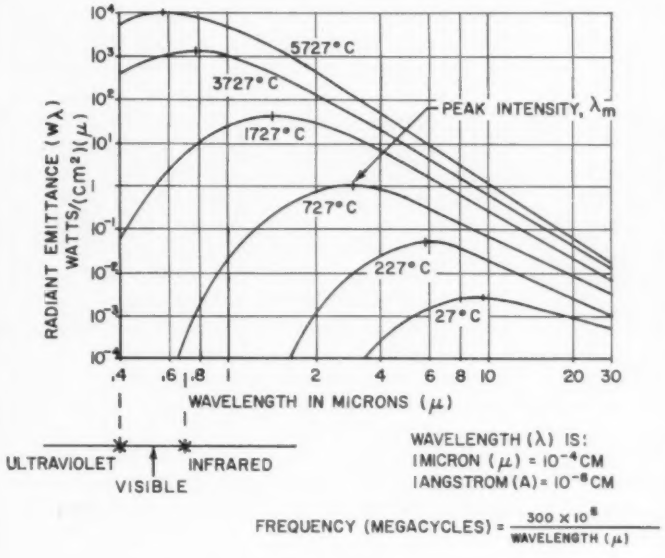
The Digest will be divided into three main parts: physical principles in their most practical aspects, detectors (costing less than about $25.00) and how to use them, and commercial applications of varying complexity.

Physical Principles

All objects at a temperature above absolute zero (−273°C or 0°Kelvin) radiate. This electromagnetic radiation has a rather wide frequency distribution, but the amplitude and frequency of its maximum intensity is a function of temperature. This effect is demonstrated in Figure 1 which also defines some of the more important aspects of the physical problem.

Figure 1 notes that visible radiation occurs at about a minimum wavelength of 0.4 microns for violet and at about a maximum wavelength of 0.7 microns for red. Above 0.4 microns the radiation is called "ultraviolet" and below 0.7 microns it is called "infrared".

The theoretical calculations presented in Fig 1 determine the radiation emittance curve. An important assumption in deriving the relationships is that the radiating source is a "black-body". The degree to which a practical source approaches "black-body" radiation is called the emissivity factor. Figure 2 lists a number of emissivity factors for various "gray-bodies" at room tempera-



1. RADIANT EMITTANCE AT WAVELENGTH λ IS:

$$\omega_\lambda = \frac{C_1}{\lambda^5}\left(e^{C_2/\lambda T} - 1\right)^{-1} \text{ WATT/CM}^2$$

λ = WAVELENGTH IN CM
C_1 = 3.7402 × 10^{-2} WATT CM²
C_2 = 1.43848 CM DEGREES
T = DEGREES KELVIN

2. WAVELENGTH OF PEAK EMITTANCE IS:

$$\lambda_m = \frac{2897}{T} \text{ MICRONS}$$

3. PEAK EMITTANCE IS:

$$\omega_{\lambda m} = 1.3\,T^5 \times 10^{-18} \text{ WATT/CM}^2$$

4. TOTAL EMITTANCE IS:

$$W = \sigma T^4 \text{ WATT/CM}^2$$

$$\sigma = 5.673 \times 10^{-2} \text{ WATT/(CM}^2)(\text{DEG.}^4)$$

Fig 1 Black-body radiant emittance vs wave length. The amount of radiation falling upon a detector depends not only upon the total emittance of the source, but also upon: a) the radiation pattern of the source (its shape and attitude); b) the solid angle of radiation intercepted by the detector and/or its radiation collecting system; c) atmospheric scattering and absorption, and the efficiency and distortion of the collecting system.

RADIATING SURFACE		EMISSIVITY FACTOR
HIGHLY POLISHED	SILVER	.03
	ALUMINUM	.08
POLISHED	NICKEL	.12
	COPPER	.15
	IRON	.24
OXIDIZED MONEL METAL		.42
ALUMINUM PAINT		.50
POLISHED BRASS, OXIDIZED COPPER		.60
OXIDIZED STEEL		.70
BRONZE PAINT		.80
ASBESTOS PAPER, LAMPBLACK		.93
IDEAL BLACK BODY		1.00

Fig 2 Emissivity factors of various room temperature surfaces (from *Handbook of Chemistry and Physics*, 30th Edition).

ture. In practice, the emissivity factor will change to some degree with the temperature of the object's surface.

Uses and Problems

Assuming this radiation can be detected, what can be done with it? It could be used to measure temperature, sense color or the frequency of the radiation, detect the presence of some elements which absorb a particular frequency of radiant energy, determine the position of the source, or determine the position of an object between the detector and the source. These are only a few of its uses, but they illuminate some fundamental problems. All the applications listed require the generation, transmission, collection and detection of the radiation. Each of these elements in the chain present a number of problems.

Generation

The generation of radiation is covered somewhat in Figure 1. Intensity and frequencies of the radiation, however, will vary with application. A simple light bulb can be an extremely good source, but, if there is too much background illumination, the system can become confused. One solution would be to use a stronger source such as a carbon arc; another solution would be to code the source by interrupting the radiation at a known rate either with a mechanical shutter (chopper) or by pulsing a neon lamp. The frequency of the interruption can be used in the detector's amplifier as the center frequency of a sharp filter so that all other frequencies of variation in the incident radiation are attenuated. If the interruptions occur at a rate of say 400 cps, then both a steady radiation and a 60 cps varying radiation could be discriminated against. One last solution might be to use a very narrow beam optical lens system which accepts radiation from only a small area in which the desired source is located. This solution, of course, is good only in an application where the source is known and fixed in position.

Another source often encountered is a gas vapor lamp. These lamps radiate energy in only a few very narrow frequency ranges depending upon the nature of the gas. This characteristic of vaporized materials to have what might be called "resonant frequencies" is used in chemical engineering to detect the presence of the vapor by the fact that it absorbs energy at these frequencies.

Transmission

The effect of transmitting radiation can be a very important problem when the source is weak, far away, or when the characteristics of the source or the transmitting medium are to be measured. The first two situations occur in taking infrared pictures and in detecting and tracking military targets. In both cases the attenuation characteristics of the atmosphere are important and a great many studies on the subject have been published. Atmospheric influence is a function of frequency; a number of "windows" or relatively unaffected ranges have been found. The visible spectrum, of course, is one, but others depend upon the water vapor, carbon dioxide, dust particles etc. which are encountered along the radiation's transmission path.

Collection

Collecting and focusing incident radiation upon a detector is exactly the same as collecting and focusing light upon the eye. This aspect of the problem is well known and beyond the scope of this article.

One interesting point can be made for "transmitting" light along lucite guides. When radiation is focused or is incident on the polished end of a lucite rod, it will be transmitted, with rather good efficiency, along the rod. Other materials can be used, but lucite is good because it is transparent, malleable and has a large "critical angle". The "critical angle" is the maximum angle incident light can make with the interface to air and be completely reflected (no radiation refracted through the interface). Lucite has a critical angle of about 42° which means that it can be bent quite radically and still be an effective transmitting device.

Detection

Radiation is of no use unless it can be detected. Historically the eye was the first detector and lead to emphasis on visible frequencies. There are, however, many other detectors that are not as critical. In general, three classes exist: thermal, photoemissive, and photoconductive.

Thermal detectors are elements which can change characteristics when they are heated. One type called bolometers change in resistance like a thermistor when it is heated. It is rather evident that this type of detector will be sensitive to a wide range of frequencies since it measures the total incident radiation, but its response will be slow since it must cool and heat. Actually bolometers have been made to achieve good results with extremely careful design and manufacture. They have also been used at very low temperatures for improved response time.

Another type of thermal detector is the radiation thermocouple. It acts like any thermocouple in that heating the junction generates a Seebeck voltage proportional to temperature. This type of detector was used in many of the original infrared experiments. It has the same drawbacks and advantages as the bolometer.

The photoemissive effect is used in photomultiplier vacuum tubes where electron emission from the cathode increases with light. This type of detector is rather sensitive and fast. It will respond to radiation in about the 0.4 to 1.1 micron region. The main disadvantage of this type is power

output, especially when compared to that of photoconductive detectors.

Photoconductive detectors depend upon materials which generate free electrons when bombarded by radiant energy. Materials such as copper and aluminum which are good electrical conductors have many free electrons and do not notice a few additions. Other materials have molecules which hold their electrons so tightly that the incident energy must be very high frequency (high energy content in photon) before any electrons are released. Semiconductors, on the other hand, are so named because they are right in the middle and experience a good sensitivity to incident radiation.

The release of free electrons can be measured in two ways, by the decrease of electrical resistance in the semiconductor material itself or by the effect of free electrons on a typical semiconductor junction. This junction is the common "pn" and is normally used as a diode. The effect of radiation on the junction can be measured either as a voltage which is generated across the junction or by the excess of minority carriers (leakage) through the diode.

The great interest in the military applications of infrared has brought out a rash of new detectors. These detectors are at present expensive, many of them require liquid nitrogen or hydrogen temperatures, and most of them have only been built in prototype quantities. There is every reason, however, to believe that in the near future some of these very exotic detectors will come into popular use.

For the purposes of this article the detectors given detailed consideration will be limited to those costing under $25.00, made in production quantities, and operating at room temperature. Older types of detectors such as bolometers and photomultiplier tubes will be neglected in favor of the newer photoconductive types.

Units For Measuring Detector Illumination

Before we consider details of the various photoconductive detectors, some general comments should be made about measuring detector illumination and evaluating detector performance.

From our discussion on black-body radiation, we would expect that the most obvious unit for measuring radiant emittance would be watts/cm². Historically, however, the emphasis, as previously mentioned, has been upon visible radiation and not total electromagnetic emittance. This has lead to a common practice, especially among detector manufacturers, of measuring incident radiation in foot-

KEARFOTT VERTICAL-SENSING ELEMENTS

Two basic precision vertical-sensing elements are available, pendulous or bubble types. These devices can be applied to any vertical-sensing application requiring an electrical output indicative of displacement from gravity vertical. Sensing elements, employing electrolytic or electromagnetic pickoffs, are made in single- and two-axis types for either signal or power applications. A servo motor may be directly controlled by the power type for low-cost, moderate-accuracy applications. In addition to these proportional units, on-off switching devices are available. Precision leveling to a few seconds of arc may be accomplished with the signal types and external amplification.

The pendulous vertical-sensing elements employ a frictionless flexure suspended mass. Displacement from vertical, sensed about two orthogonal axes results in proportional phase-sensitive ac voltage outputs. The bubble types, of glass and noble-metal construction, contain an electrolyte and a gas bubble which acts as the gravity sensor. High reliability, low cost, and excellent resistance to vibration are achieved.

CHARACTERISTICS

	Part Number	Type	Excitation	Range	Null Repeatability
Pendulous	B1802-01	Electrolytic	400 cps*	1.3°	4 min.
	C70 1807 000	Electromagnetic	10 v 1000 cps	20 min.	4 sec.

	Part Number	No. Axis	Type Output	Range	Null Repeatability
Bubble	C70 1808 000	1	Proportional*	1° nominal	To 4 sec.
	A1800-01A-A	2	Proportional*	1° nominal	5 arc min.
	228571-1	1	On-Off*	Switches at 0.75°	Range 75-135 arc min.

NOTE: *Above designed for 400 cps., but higher frequencies possible. Excitation voltage is a function of circuit impedance.

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KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

CIRCLE NO. 30 ON INQUIRY CARD

COMPONENTS DIGEST

TABLE I

THE RELATIONSHIP BETWEEN FOOT-CANDLES AND WATTS/CM²

1. W_λ = radiant emittance at wavelength λ from source in watts/cm² at λ (see Fig. 1).

2. $W = \int_0^\infty W_\lambda \, d\lambda$ = total radiant emittance in watts/cm²

Note that cm above refers to source area and not detector area. Total radiated power from a point source is distributed over 4π solid angles. A radiant flux of 1 watt/cm² across a detector would occur when the detector is 1 cm from a source emitting a total of 1 watt in all directions (W times source area in cm²).

3. V_λ = Relative luminosity factor at wavelength λ, which is a simple attenuation proportional to the eye's sensitivity. It is unity at 0.555 microns, and zero at about 0.4 microns and 0.7 microns, as shown in Fig. 3.

4. Luminosity $= 685 \int_0^\infty V_\lambda W_\lambda \, d\lambda$ lumens and is the total visible power given off by the source.

5. Intensity $= 685 \int_0^\infty V_\lambda W_\lambda \, d\lambda / 4\pi$ candles and is the measure of the source in candle power.

6. Radiant Flux is measured in foot-candles

1 foot-candle = 1 lumen/ft²

or the illumination at a distance of one foot from a point source of one candle power.

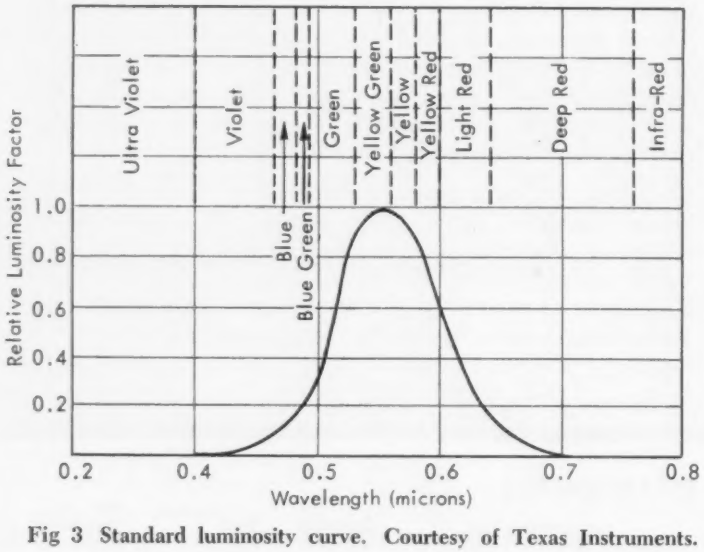

Fig 3 Standard luminosity curve. Courtesy of Texas Instruments.

candles instead of watts/cm². The relationship between visible and total radiation are shown in Table I.

Figure 1 showed the total emittance in watts/cm². This must be multiplied by the source area in cm² to get total power radiated in watts. This total power, from a point source, will be given off in all directions or across 4π solid angles. The radiant flux is, therefore, total watts divided by 4π and a detector at a distance of 1 cm from a source whose total power is 1 watt will see a flux of 1 watt/cm².

This same set of statements can be made about visible power. The relationship between the total electromagnetic radiation discussed above and the visible radiation is defined by the "visibility curve" in Fig 3. The visibility curve matches the eye's sensitivity and weights the radiation accordingly. The units of lumen are similar to watts, but the source intensity is defined by candle power. A one candle-power source is one which gives off 4π lumens as its total radiant power in all directions. Foot-candles are related to watts/cm² by the fact that 1 foot-candle is 1 lumen/ft² or the radiant flux seen by a detector at 1 ft from a 1 candle power source. A standard for a one candle power source is 1/60 the intensity of a one square centimeter black-body radiator at the temperature of solidification of platinum (1773°C).

Generally the detector performance is measured by the manufacturer using a tungsten lamp at a particular "color temperature." Color temperature is defined as the temperature of an incandescent source where its spectral distribution most nearly equals that of a black body at the same temperature, see Fig 1.

DETECTOR PERFORMANCE CRITERIA

A large number of performance criteria for photo and infrared detectors have been proposed. Basically there are: speed of response, sensitivity to signal and noise, and spectral response. A number of attempts have been made to combine all the above factors into one figure of merit. In most industrial applications, however, noise is not the problem and evaluating detector performance usually rests upon sensitivity to signal and speed of response.

The speed of response is generally measured by a *time constant* (τ), defined as the time it takes for the detector output to reach 63% of its final value after a step increase in illumination. It generally takes longer for a step decrease in illumination. The time constant can be hard to measure because many detectors don't respond in a nice first-order exponential way. Speed of response will also be affected by temperature, intensity of the change in illumination, the past history of the illumination, and the radiant frequency.

Signal sensitivity is usually called *responsivity* (R_v) and is the signal output per unit of incident radiation; for example: microamps/foot-candle. The only trouble is that this figure again depends upon temperature, type of illumination (pulsing or steady), radiant frequency, and test circuitry used in measuring output signal.

Relative spectral response ($R\lambda$) can be more easily defined as the ratio of the responsivity at any wavelength divided by the responsivity at the detector's most sensitive wavelength.

Noise is any output not related to the desired signal and can be caused by internal effects or from the background as seen by the detector. In

industrial applications the detector is generally not used in applications where the internal noise is a problem, and the external noise is, of course, a function of the particular application. If internal noise were a problem it could be measured by the *noise equivalent input* (NEI) or *noise equivalent power* (NEP). This criterion is defined as the equivalent illumination which just produces a signal to noise ratio of unity. This figure is sensitive to detector area, temperature and test circuitry. A more complete measure of signal to noise is called *detectivity star* (D*); it is the square root of the area of the detector times the bandwidth of the detector circuitry divided by the NEP.

SEMICONDUCTOR DETECTORS

The four semiconductor detectors, mentioned previously, are photoconductive, photovoltaic, photodiode and phototransistor.

Photoconductive detectors are simply semiconductor materials which, when exposed to radiation, decrease in resistance. Table II shows an example of this device in the form of a Clairex type 403 unit. This unit happens to be made of Cadmium Selenide but there are a great many other materials which can be used. Actually lead sulfide is the most popular.

Table II roughly demonstrates how the data curves can be used to design a basic circuit using the 403 and a transistor to actuate a relay. In Tables III, IV, and V the other semiconductor detectors are also shown in a transistor circuit with a relay load. Each Table, moreover, lists the general range of parameters for the various detector types.

The second type of semiconductor detector is the photovoltaic or "solar" cell. This device is basically a very large semiconductor junction exposed to illumination over its whole area. Actually photovoltaic detectors have been used for some time in the form of selenium to metal junctions. Table III, however, indicates the advance in performance of a silicon cell, although selenium cells are still used widely because of their more flexible shapes. Table III also shows examples of data curves, the range in parameters and a typical circuit to actuate a relay.

The approximate small signal equivalent circuit in Table III is very interesting because it will be the same for photodiodes and phototransistors. The main difference between a photovoltaic cell and a photodiode is that the junction area is much larger in a photovoltaic device. This large area is required for high energy conversion,

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TYPICAL PERFORMANCE DATA

Unit No.	R980-41D	T980-003	CZ05180202
Size	11	15	25
Accuracy (Max Error from E.Z.)	5 minutes	5 minutes	20 seconds
Function Error	.1% max	.05% max	.01% max
Excitation (400 cps)	60 volts	60 volts	115 volts
Transformation Ratio (Rotor to Stator)	980±.020	980±.010	980±2%
Phase Shift	7.5 lead	8.5 lead	2.5°±1 min

Write for complete data

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COMPONENTS DIGEST

the usual function of a "solar" cell. The photodiode is basically a small semiconductor diode with a very small opening at the junction. Many units have a small lens in this opening to focus the illumination on the small junction area, making the device very directional. The photodiode is, in general, faster and usually less sensitive than the photovoltaic detector. The phototransistor, on the other hand, is simply a transistor with its base to emitter junction exposed. This means that the current in the base is proportional to illumination instead of the normal base voltage. The phototransistor operates at about the same speed as the photodiode but has more sensitivity due to its amplification, although the dark current is also greater.

The equivalent circuit for the semiconductor detectors, as in Table III, is a current source proportional to illumination. The proportionality factor k is similar to α usually used in transistor circuits and has the units of microamps/foot-candle. The factor k can be seen to equal *responsivity*, R_s mentioned previously. $R\lambda$ is the relative response plotted for each detector. In the photovoltaic case factor k depends upon cell area and in the photodiode and phototransistor cases, k is somewhat a function of bias voltage. Two resistances make up the remainder of the equivalent circuit: R_{sh}, a large shunt resistance representing the back biased diode leakage, and R_s, a small series resistor representing the terminal impedances. Actually, as in any equivalent circuit, the parameters are only accurate over a small range, which is evident from Tables III, IV and V. The parameters are especially sensitive to temperature. This problem will be discussed in the next section.

Table IV shows a very interesting example of the photodiode, using a Texas Instrument IN2175 "dual diode" detector. This unit is two diodes back-to-back. One diode acts as a photodiode by varying its back biased leakage current with illumination while the second diode is simply forward biased. This means that either AC or DC can be used as the bias voltage.

Table V shows the general range of parameters for a phototransistor. The example chosen is a Texas Instrument type 800.

TABLE II

PHOTOCONDUCTIVE DETECTOR CHARACTERISTICS

Typical Performance Curves (example is Clairex Type 403 photoconductive detector)

General Characteristics at Room Temp.

1) Dark impedance, $R_{SH} \approx >0.1$ to 10 meg. ohms

2) Time constant, $\tau \approx 200$ to 10,000 x 10^{-6} sec.

3) Appropriate sensitivity is extremely difficult to determine since resistance changes exponentially, with the greatest change at the lowest illumination levels, as can be seen from the milliamps vs volts data curve.

4) Peak frequency, $\lambda_m \approx 0.5$ to 1.0 microns; depends upon the semiconductor material.

5) Size and shape almost unlimited.

6) Equivalent circuit: Variable resistance (see milliamps vs voltage curve)

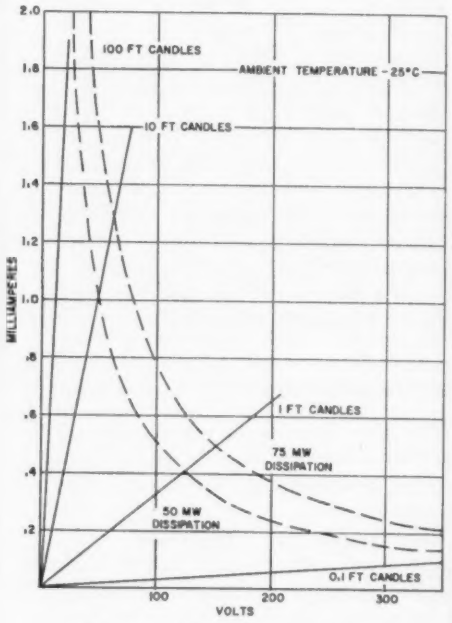


Fig IIa Milliamps vs volts

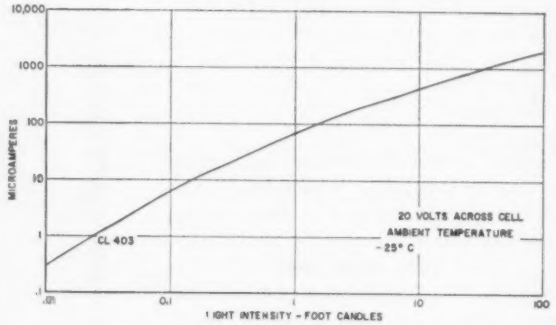
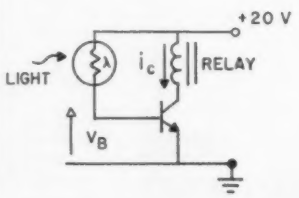


Fig IIb Microamps vs foot-candles

7) Typical circuit:



This circuit is extremely temperature sensitive, but as a first approximation, the current shown in the relative response vs angstroms curve can be multiplied by the β to give i_c.

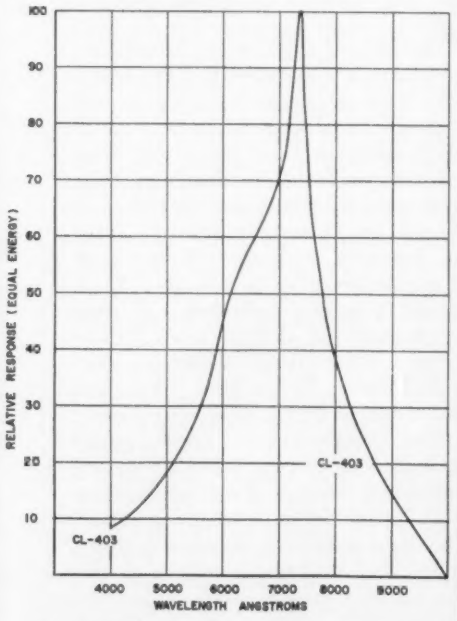


Fig IIc Relative response vs angstroms

A new type of photocell that promises to simplify a wide variety of light controlled electronic and electromechanical systems was recently announced by Solid State Products Inc. of Salem, Mass. Characterised as a photoswitch, this new device, called a Photran, has many properties similar to those of a gas thyratron. It is essentially a PNPN switch that is triggered by light energy instead of (or in addition to) electrical energy. Before light strikes the Photran it is in a high impedance "off" state. When a light impulse is applied, it switches to a low impedance "on" state and remains "on" until it is electrically turned "off". Light energy used to trigger the device "on" need only be momentary since it is not required to sustain the "on" state. In comparison with other photocells the response time of the Photran is fast, permitting its application to high speed control systems.

Because of its newness and because of its unique binary memory, large power handling ability and high speed that open the way to many new designs in optical control, the Photran warrants a separate article in the Components Design section of this Issue describing in more detail its performance characteristics and some of its more important circuit applications.

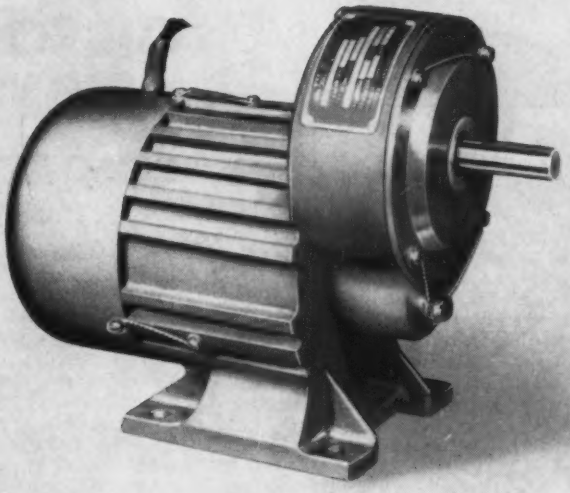
Application Techniques

In each of Tables II through V, a semiconductor detector was shown operating a relay. All four circuits had about the same problem: drift with temperature in the detector and the transistor. For the relay circuit this characteristic might not be bad, but it could lead to activating the relay with only the background illumination on the detector. In other applications the effect of drift can be even more direct.

The photovoltaic detector is the least sensitive to temperature, but a bias network has to be used for the transistor, at least for silicon transistors. If the transistor were germanium no bias would be needed, but there would be no base current until the cell develops more than the normal base to emitter blocking voltage (about 0.250 at room temp.).

In the other detector cases, the quiescent collector current will vary with dark impedance and normal transistor leakage current, I_{CBO}. Also, since the stability factor (change in collector current for a change in I_{CBO}) is high due to low emitter impedance and high input impedance, the effect of I_{CBO} will be very large.

To achieve a better circuit the transistor must have a lower stability



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COMPONENTS DIGEST

factor. This can be obtained with a reasonable emitter resistor and a resistor from base to ground. Both the added resistances tend to shunt the signal, reducing gain.

The effect of detector drift can be minimized by having the dark impedances at two detectors compensate each other in a bridge. This means that the two detectors must be matched for characteristics and must be kept in the same ambient. Only one detector need be illuminated because, as in Table IV curves *c* and *e*, it is the dark impedance and not light sensitivity that varies greatly with temperature.

The best solution for both detector and transistor drift is to modulate the signal. If the signal is interrupted at a fixed, rather high rate, the proposed large emitter resistor can be bypassed with a capacitor increasing gain and at the same time decreasing the stability factor. The detector can also be detached, loaded with a high impedance, and reconnected to the base through a large capacitor. This greatly reduces the effect of the slow change in the dc level across the detector, due to drift in the dark impedance, on the bias of the transistor. An added feature of coding or modulating the signal is that the background illumination and noise can be discriminated against. For example, if there are a number of fluorescent lamps in the environment, they can produce a large 60 cps component. This component, as well as the dc or steadier background light from incandescent sources, can be filtered if the true signal is modulated at a rate well above 60 cps. The filtering is achieved with a simple resistance and capacitance high pass filter.

The main problem is how to modulate? Two techniques are popular: applying an oscillating signal to a neon lamp or interrupting the beam from a steady source. The neon lamp, however, requires considerable power, is short-lived, and is quite dim. Interrupting a beam requires a mechanical shutter or disk and produces a number of rather evident disadvantages. One advantage, however, of the rotating disk is that the size of the signal source can be differentiated. If the disk is made of small light slots, only an object appearing about the same size as the slot will be interrupted at the coded rate. A larger object will

not vary in average incident radiation at the detector and will, therefore, not appear, after the filter, as a signal.

Examples

Four examples of photoconductor applications will be given. The first two are general types of use and are rather straightforward applications of the elementary techniques presented in the last section. The second two examples are more sophisticated and are included to demonstrate the type of instruments that are being designed today.

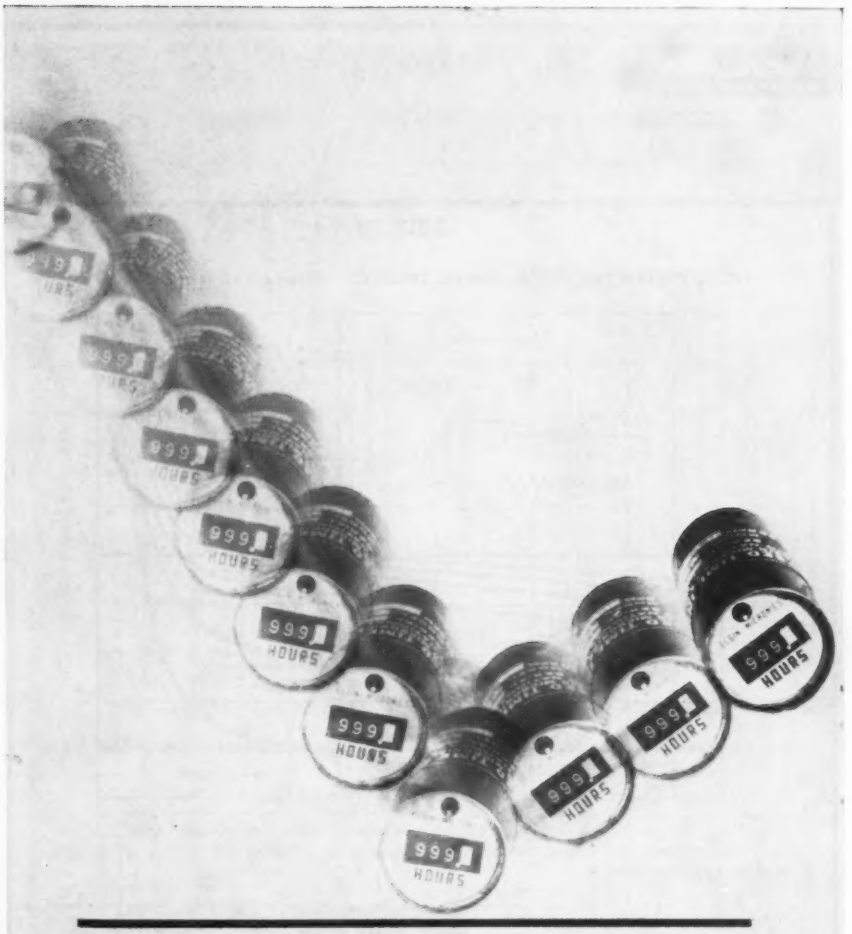
The typical circuits shown in Tables II, III, IV and V were "discontinuous" in that they were intended to operate only when the illumination was turned off or on. This operation could be used to count work pieces on a conveyer belt or holes in a data processing paper tape or punched card. It could also determine when a person approaches a door or when a work piece reaches a preset position. Another example is detecting liquid levels by reflecting radiation off the surface so that the detector is illuminated at a preset level. The illumination source is often included in the same housing with the detector which means that a reflector must be used. A number of corner type reflectors have been used to minimize the sensitivity to angle between the source and the reflector surface.

The second type of general system is proportional. A typical example would be two silicon photovoltaic cells imbedded in a table, end-to-end. Position of a work piece can be measured by using the detectors in a bridge. One cell could be used, but drift would then be much worse. Measuring the incident radiation on a detector in this way obviously presents many problems due to characteristic variations. Use of signal modulation in a proportional system is even more valuable than in a discontinuous operation.

Continuous measurement of detector illumination is also used in remote heat indicators. This example operates on the fact that radiation and source temperature are related. The problems in this case are due more to the natural laws of radiation than to the detector circuitry.

Infrared Detection

For many applications, limiting a photodetection system to detection of infrared radiation offers an important advantage: infrared can be reflected from the body to be detected thus avoiding the necessity of installing the transmitter and detector in separated



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COMPONENTS DIGEST

TABLE III

PHOTOVOLTAIC DETECTOR CHARACTERISTICS **Typical Performance Curves**

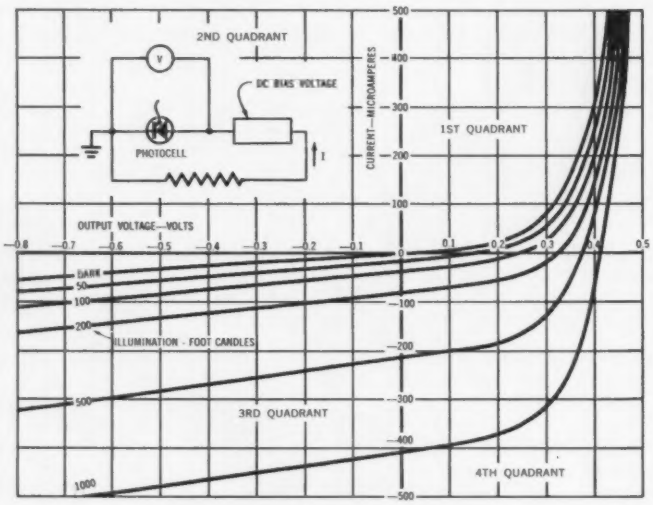
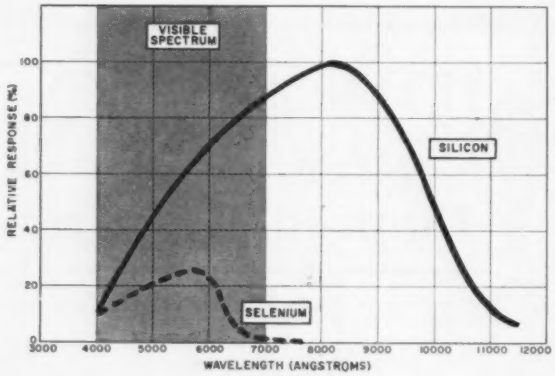


Fig IIIa Microamps vs volts for silicon photocell reader; active cell area 0.01 in², cell temperature 30°C and tungsten light source at 2850°K. (Courtesy of International Rectifier Corp.)

Fig IIIb Relative response vs angstroms (Courtesy of Hoffman Electronics Corp.)



General Characteristics at Room Temp.:

1) Dark impedance, $R_{BB} \approx 0.1$ meg. ohms

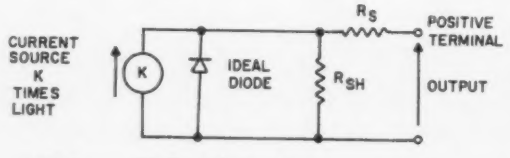
2) Time constant, $\tau \approx 20 \times 10^{-6}$ sec.

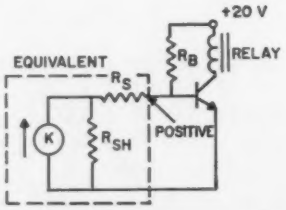
3) Approximate sensitivity, $K \approx R_o \approx [0.1 \times 10^{-6}$ amps/(cm²)]/foot-candles

4) Peak frequency, $\lambda_m \approx 0.8$ to 1.0 microns

5) Size and shape generally limited, in silicon, to rectangles with an area of about 0.01 square inches. They can also be obtained in other sealed configurations of about the same area.

6) Equivalent circuit, for small signals:





7) Typical circuit:

This circuit requires a large R_B which is set to provide enough current to bring the base just into conduction. The cell will then see a low impedance which approaches the short circuit condition. With this load the cell has the lowest temperature sensitivity.

TABLE IV

PHOTODIODE DETECTOR CHARACTERISTICS

Typical Performance Curves (Example) is Texas Instrument Type IN2175)

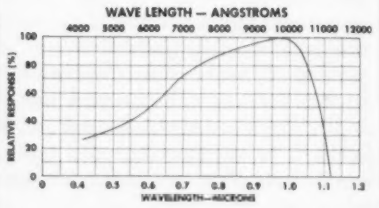


Fig IVa Relative response vs angstroms, for equal values of radiant flux at all wave lengths.

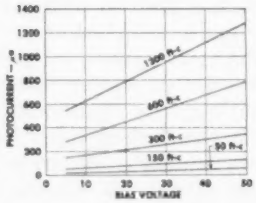


Fig IVb Photocurrent vs bias voltage at 25°C for different illumination intensities. Light source is tungsten filament lamp operated at color temperature of 2870°K.

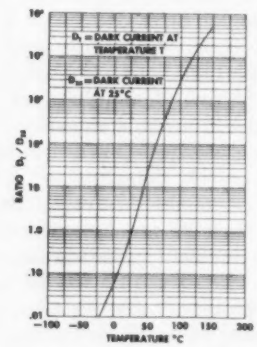


Fig IVc Typical dark current characteristic vs temperature, for any constant voltage between 10 and 50 v.

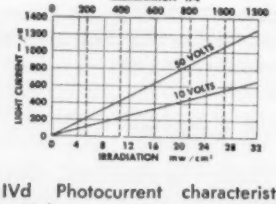


Fig IVd Photocurrent characteristic at 25°C. Light source is tungsten filament lamp operated at a color temperature of 2870°K. Radiation flux transmitted through Dow Corning deep red filter (CS 7-69) measured at exit surface with Eppley Lab. thermopile.

TABLE IV *(Continued)*

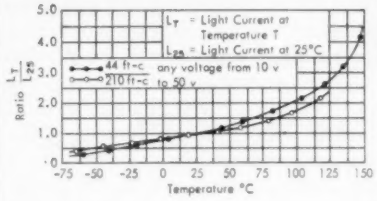


Fig IVe Light current characteristic vs temperature.

General Characteristics at Room Temp.:

1) Dark impedance, $R_{SH} \approx 10$ meg. ohms

2) Time constant, $\tau \approx 2 \times 10^{-6}$ seconds

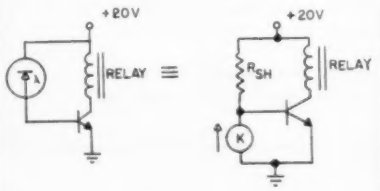
3) Approximate sensitivity, $K \approx R_v \approx 1 \times 10^{-6}$ amps/foot-candles

4) Peak frequency, $\lambda_m \approx 0.8$ to 1.0 microns

5) Size and shape. Small cylinder about the same diameter as a small diode except generally longer with leads at one end and an opening or lens at the other.

6) Equivalent circuit same as Table III but with different sensitivity.

7) Typical circuit:



This circuit is extremely temperature sensitive because of the variation in both R_{SH} and quiesent collector current. The stability factor is extremely high, but variations in the base to emitter impedance will not be important because of the high source impedance of the photodiode.

equipment on opposite sides of the area to be monitored. The transmitter and detector can be located together at any position such that the range is within the sensitivity of the equipment and the transmitted and received beams are not obstructed.

Background objects can be discriminated against by using a narrow-beam optical system and orienting the detector with respect to the transmitter so that only reflected beams from objects in the precise range of the area to be monitored will be detected.

Another advantage of an infrared system is its insensitivity to environmental light.

To illustrate some of the major design considerations in development of an industrial photoelectric detection system we asked Infrared Industries

TABLE V

PHOTOTRANSISTOR DETECTOR CHARACTERISTICS

Typical Performance Curves (Example is Texas Instrument Type 800)

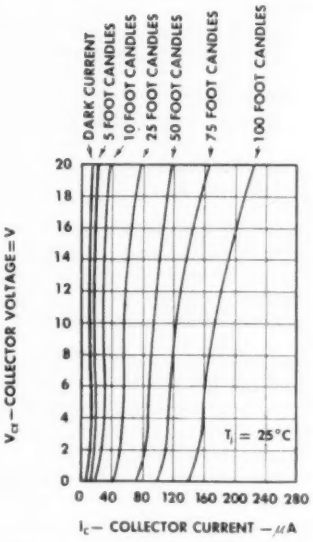


Fig Va Collector voltage vs current

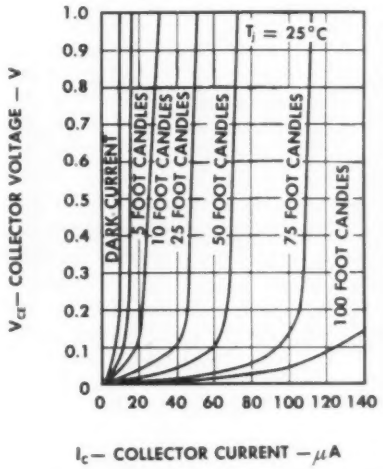


Fig Vd Colllector voltage vs collector current expanded

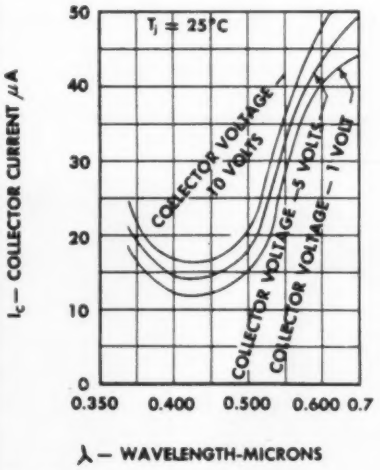

I_c – COLLECTOR CURRENT μA
T_j = 25°C
COLLECTOR VOLTAGE – 10 VOLTS
COLLECTOR VOLTAGE – 5 VOLTS
COLLECTOR VOLTAGE – 1 VOLT
0.350 0.400 0.500 0.600 0.7
λ – WAVELENGTH-MICRONS

Fig Vb Collector current vs wavelength

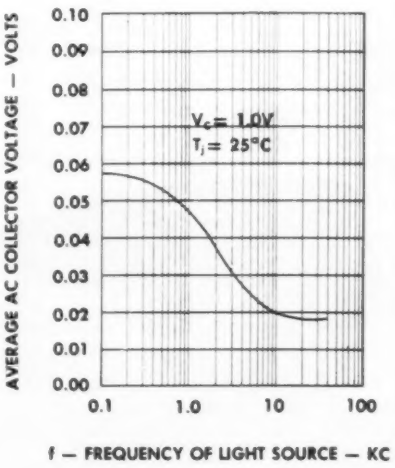


Fig Ve Average ac collector voltage vs frequency of light source

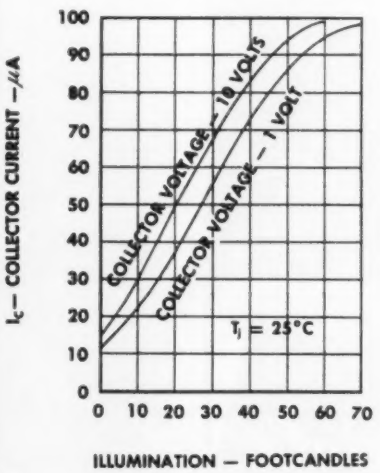

I_c – COLLECTOR CURRENT – μA
COLLECTOR VOLTAGE – 10 VOLTS
COLLECTOR VOLTAGE – 1 VOLT
T_j = 25°C
0 10 20 30 40 50 60 70
ILLUMINATION – FOOTCANDLES

Fig Vc Collector current vs illumination

General Characteristics at Room Temperature:

1) Dark impedance, $R_{SH} \approx 1$ meg. ohm

2) Time constant, $\tau \approx 2 \times 10^{-6}$ seconds

3) Approximate sensitivity, $K \approx R_v \approx 5 \times 10^{-6}$ amps/foot-candles

4) Peak frequency, $\lambda_m \approx 0.8$ to 1.0 microns

5) Size and shape about the size of a small signal transistor with an opening on the top and two leads instead of three on the bottom.

6) Equivalent circuit: same as Table III but with different sensitivity.

7) Typical circuit: same as Table IV.

COMPONENTS DIGEST

Inc. to describe the design of their Infrabeam unit, (also marketed by Cramer Controls Corp.) pointing out factors that influenced selection or design of components. Here is the description as told to us by Ernest Bivans, Technical Director of Infrared Ind., Inc.

Infrabeam is an example of a discontinuous detection system that uses filters to restrict radiation to infrared and a narrow beam optical system in the transmitter and detector to restrict sensitivity to small target areas.

Transmitter

The transmitter consists of a tungsten filament light bulb and a rather simple, but efficient optical system. The tungsten bulb was selected because of its small size, availability, low cost, and long life. A narrow beam optical system requires a small source operating at relatively high temperature; marketing considerations de-

TABLE VI

BUYERS GUIDE FOR SEMICONDUCTOR PHOTOELECTRIC DETECTORS

Amperex Electronics Corp.
230 Duffy Ave., Hicksville, N. Y.

Clairex Corp.
19 West 26th St., N. Y., N. Y.

Eastman Kodak
Rochester, N. Y.

Electronic Transistors Corp.
92-26 Hudson Blvd., N. Bergen, N. J.

General Transistor Corp.
91-27 138th Pl., Jamaica, N. Y.

Hoffman Electronics Corp., Semicon. Div.
1001 N. Arden Dr., El Monte, Calif.

Hughes Semiconductor
500 Superior Ave., Newport Beach, Calif.

Industro Transistor Corp.
35-10 36th Ave., Long Island City, N. Y.

International Electronics Corp. (Mullard Equip.)
81 Spring St., N. Y., N. Y.

International Rectifier Corp.
1521 E. Grand Ave., El Segundo, Calif.

Nucleonic Prods. Co.
1601 Grande Vista Ave., L. A., Calif.

Philco Corp., Lansdale Div.
500 Church Rd., Lexington, Mass.

Semi-Elements, Inc.
Saxonburg Blvd., Saxonburg, Pa.

Syntron Co.
264 Lexington, Homer City, Pa.

Texas Instruments
6000 Lemmon Ave., Dallas, Texas

U. S. Transistor Corp.
149 Eileen Way, Syosset, N. Y.

Vickers, Inc., Electric Prods. Div.
1825 Locust St., St. Louis, Mo.

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Here is the alligator clip you can now use where no other clip will do! On printed circuits, in tight spots and on tiny terminals too crowded for anything but its "microscopic" tip. Fully insulated right down to the nose. It offers all the speed, free-handed ease and convenience associated with other Mueller alligator clips.
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INSULATORS SOLD SEPARATELY. (Standard Red and Black colors. White, Blue, Yellow and Green also available.)
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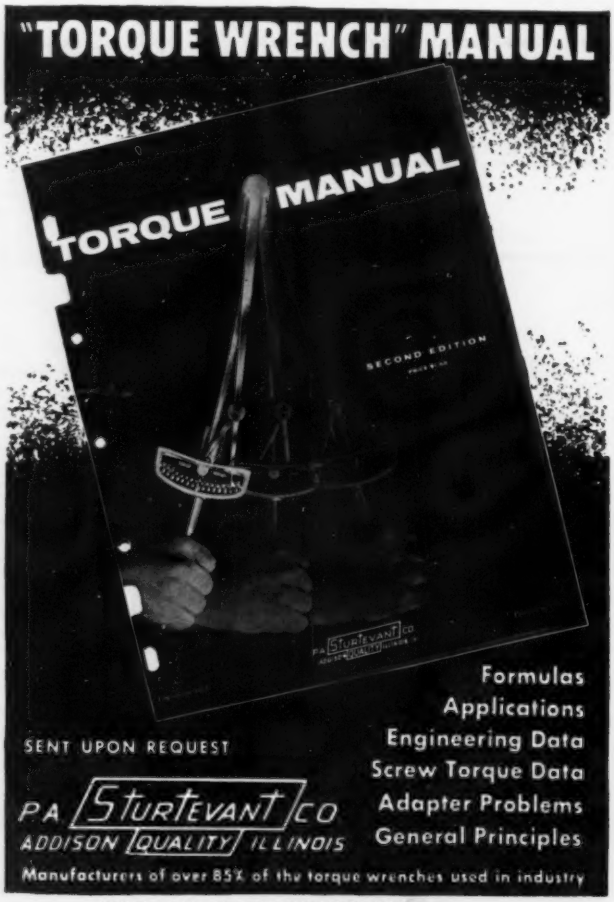
1554W East 31st Street, Cleveland 14, Ohio
CIRCLE NO. 37 ON INQUIRY CARD



CIRCLE NO. 38 ON INQUIRY CARD

mand low cost, availability and long life. The transmitter is designed to operate the tungsten bulb at reduced voltage, which assures longer bulb life without severely reducing the infrared power generated. Since the bulb is used in an optical system, the filament has to be accurately positioned so that when it is changed, refocusing or re-alignment of the system is not necessary. Tungsten bulbs with coiled filament similar to those used in automobile headlights meet these specifications. They have various indexing arrangements on the base so that they can be accurately positioned. Infrabeam uses such a bulb with a spherical reflector of about two-inch diameter. A two-inch diameter columnating lens in front of the bulb provides a narrow beam of about two degrees spread as measured to the half power point.

Gas discharge tubes, such as xenon, argon or neon, were rejected as the source because, although they have higher efficiency in the infrared region than tungsten, they are not as reliable. Other types of sources, such as black bodies, were rejected because they are too expensive.

To insure that the receiver will be relatively insensitive to background radiation, the transmitter beam is modulated at a frequency around 450 cycles a second. The higher the frequency, the easier it is to build filters and amplifier circuits, and the easier it is to discriminate against harmonics of the 60 cycle radiations generated in fluorescent and mercury vapor lamps as well as tungsten lamps. Infrabeam uses a frequency of 450 cycles because it is not a multiple of 60 cycles and is midway between the 420 and the 480 cycle components.

Chopping is done with a small synchronous motor operating at 1800 rpm and driving a six-inch diameter disk that has the appropriate number of holes drilled into it. The chopper also includes an infrared filter over the face of the optical system to exclude visible radiation. Concealing the source of the radiation has advantages for applications where hiding the presence of a detection system is desired.

Receiver

Design of the receiver was based on calculations indicating that the sensitivity of a lead sulphide infrared detector would be adequate and that signal-to-noise ratio would not be a problem if a moderate-size optical system were used. A standard Infrared Industries' detector of approximately 0.020 by 0.020 inches and a reflective type optical system with a three-inch diameter parabola were selected. With this parabola, which has an F number of about 0.3, the actual image formed is not very good, but where the purpose of the system is to collect infrared energy and not to produce a picture, good image quality is not needed.

Signal-to-noise ratio of the receiver is more than adequate to pick up infrared reflections from a small target at a distance of 15 feet. Although this signal-to-noise ratio is very good, the actual signal levels are moderately small — in the millivolt region. A fair amount of amplification is therefore needed to bring the signal level up to where it can operate a relay. A modified Schmidt trigger circuit is used in the output of the amplifier to generate hysteresis in the trigger circuit so that the relay doesn't chatter as the signal starts to become marginal.

An infrared filter is included in the receiver optical system to reduce radiation from daylight, tungsten lights and fluorescent lights thus making the unit insensitive to background radiation. Without an infrared filter the unit could not be operated in a room with more than 100 ft-candle brightness level.

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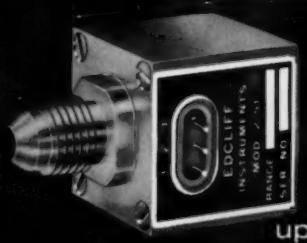

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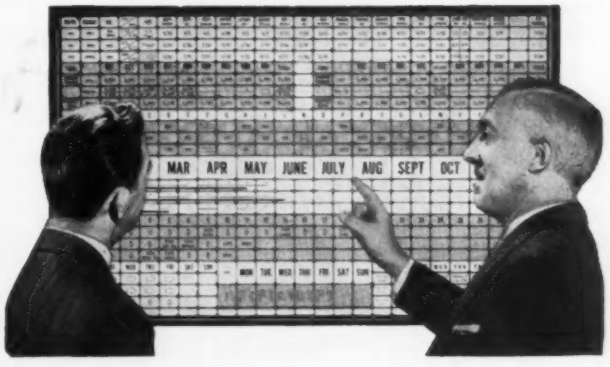

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COMPONENTS DIGEST

In addition to preventing spurious light signals and external light sources from actuating the unit, the filter also prevents high intensity illumination from reducing the sensitivity of the unit. (Saturating the detector makes it unresponsive to any but very large signals.)

Since high-quality interference-type filters, such as germanium and silicon, are far too expensive for use in commercial control units, Infrared Industries selected an inexpensive, three-layer-plastic laminated, long-pass filter that will pass all infrared radiation beyond a minimum wave length. Its cutoff frequency is about 0.8 microns which is just at the edge of the visible region. If one of these filters is held up to a very bright light such as the sun, a slight amount of light will pass through it. It is not completely opaque in the visible range but its attenuation is very high. • • •

WORTH FILING

Self-Locking Fasteners

64 page design manual scrutinizes reduced dimension, lightweight types of self-locking fasteners. It provides the design engineer with a concentrated package of nut shapes useful in assemblies intended for avionic and electronic end use. Special emphasis is given to clinch types of nuts including a new "floating" type of bind fastener and two new right angle bracket nuts suitable for panel and cover assemblies. Instructions tell "how to install" clinch nuts; available tools and production methods are illustrated.

For Your Copy: Write No. 810 on Inquiry Card
Source: Elastic Stop Nut Corp. of America
Union, N. J.

Electron Tubes

Do's and don't's of tube applications are reviewed in a 58-page booklet, "Electron Tube Application Notes". Most of the techniques described relate to equipment reliability.

Source: Sylvania Electric Prods. Inc.
New York, N. Y.
For your copy: Write No. 820 on Inquiry Card

Tunnel Diodes

General Electric's 96-page book on how to use tunnel diodes follows the pattern set by their widely used Transistor Manual. Application information is divided into four different chapters. In addition the manual contains chapters on tunnel diode ratings and characteristics and test circuits. Price: $1.00.

Order your copy from:
General Electric Co.
Kelley Building
Liverpool, N. Y.

Tables and Formulae

Valuable engineering information in a handy form, a booklet, "Tables and Formulae", contains tables of weights and measures, math symbols and constants, the Greek alphabet, temperature conversions, binary numbers, powers of numbers, electrical formulae, the fundamentals of Boolean algebra and other handy data.

Source: Automatic Electric Co.
Northlake, Ill.
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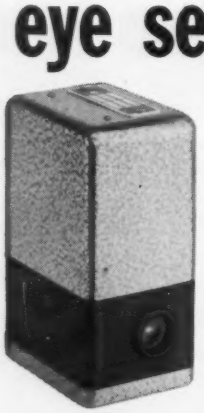

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One single package includes lamp, power supply, transistor amplifier, and photocell. Light travels out and back through one lens on one beam path. Plug into line current and you're set up for speed measurements, linear or rotational, to 100 KC. No more alignment problems, no magnetic interference or weighting of shafts with gears. HLS-20 works from light-dark contrasts or reflecting tapes to produce reliable results on your electronic counter.

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Transistor & Diode Radiators

Head radiators, specially designed for high-powered transistors and diodes, dissipate up to 200 and higher wattages while approaching the efficiency of an infinite heat sink. Radiators also function as a chassis to which the components can be mounted. Width: 4½"; lengths available in ½" increments to 12 ft. Birtcher Corp., Monterey, Calif.

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Operational DC Amplifier

Chopper stabilized dc amplifiers with high gain maintained over a wide band, are ideal in analog computation and control system applications that demand precision at high speed. Output: ±100 volts with a 10K load; it operates at 75 ma positive output and pulses to 200 ma. Output short-circuits without damage. A gain of 125,000 is available from 5 to 500 cps, and 10^8 at dc. American Brake Shoe Co., Los Angeles, Calif.

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Solid State Inverter

A dc to ac inverter, for air and space vehicle applications, weighs 3.7 lbs consuming less than 65 cu in of space. An unusual thermal design uses the connection cable as a heat sink by mounting the power transistors directly on the input-output plug. Inverter's input ranges from 22 to 32 vdc; maximum input current 5.5 amps. Magnetic Research Corp., Hawthorne, Calif.

Write No. 409 in Box on Inquiry Card

Mesa Diodes

Silicon micro mesa diodes have reverse recoveries as fast as 2 nanoseconds and capacitances of 2$\mu\mu$f. Eleven types include electrical equivalents of EIA types of IN904 through IN916. Reliability is said to be equal to or greater than conventional diodes. Pacific Semiconductors, Inc., Hawthorne, Calif.

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Delay Timer

Time delay relay unit is said to be the only available timer that will time in both directions, at different rates of time using the same motor. One clutch mechanism allows this minimum-maintenance timer to be reset from zero instantaneously. Special adjustable load pointer can be set between certain time limits allowing the relay to control an outside circuit. This permits the load switch, turned on at a predetermined time, to stay on until the timer is either reset or returns by the pointer under power. The timer automatically shuts off on reaching maximum time or upon reaching zero. Unit operates on 115 v ac and contains its own dc power supply. All environmental tests have been met for military use. McElroy Electronic Corp., Littleton, Mass.

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ELECTRICAL CONTROL PANEL ENCLOSURES

TWO DOOR, FLOOR MOUNTED ENCLOSURES

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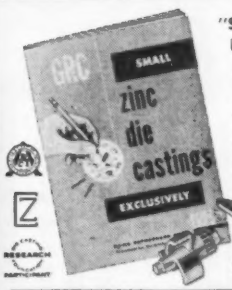

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Micro Relay

Meeting all the requirements of Mil-R-5757D, a 4 pole double throw relay, the Astrorelay, is contained in a ½ oz. package. Standard units withstand vibrations of 30 G's 10-5000 cps: 40 G's 10-2000 cus. Special versions are immune to 50 G's 10-5000 cps. The relay will operate over a −65 to +125°C micro relay with a pull in power of approximately 250 milliwatts. Kurman Electric Co., Brooklyn, N. Y.

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Jet Pump Motor

No motor assembly required with a jet pump motor designed for complete integration with the pump it drives. The "uni-built" motor uses part of pump housing in place of conventional motor end frame. Throughbolts secure motor to pump. Rated ⅓-1 hp, 3600 rpm, single or 3-phase, the pump motor features an enclosed capsule starting switch. A. O. Smith Corp., Tipp City, Ohio.

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Designed as a computer core driver, microminiaturized silicon diodes at 25°C, are characterized by a stored charge of 25mm C/mA, forward voltage drop of 1.5 v at ½ amp and 6 micro sec recovery time. Units exhibited excellent moisture integrity under exhaustive tests and achieved reliability histories substantially better than conventional-size diodes. Pacific Semiconductors, Inc., Hawthorne, Calif.

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Subminiature Thyratron

Consuming no power at standby and triggered by 95 v dc, a subminiature thyratron tube specially suits applications in timers, electronic relays, counters, overvoltage protection circuits and wherever a miniature clipper tube is required. The tube, a size T2 glass bulb triode with a cold cathode, operates on an anode supply of 200 v dc at a resistance of 30K ohms. Transfer current: 0.5 ma dc, maximum average. Electronic Industries, Inc., So. Norwalk, Conn.

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Voltage Regulators

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With guaranteed repeatability of 30 sec, accuracy ±6 min and slow speed 9° per sec, new servo units indicate remote shaft positions of 400 cps synchros, resolvers or potentiometers. Readout, numerically displayed in degrees and minutes, reads to 30 sec. Astrodyne, Inc., Caldwell, N.J.

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Dual Blowers

Incorporating sealed ball bearings that require no maintenance, new, light weight, dual blowers generate a total free air delivery of 150 cfm; at 0.4 static pressure, they deliver 90 cfm. Dimensions of motor and blowers assembly is 7¾" width, 6⅜" top to bottom. Particularly recommended as a rack blower, they disperse heat generated by electronic equipment, induction heaters, instrument cabinets and transmitter cubicles. Ripley Co., Inc., Middletown, Conn.

Write No. 444 in Box on Inquiry Card

DC Converter

Ideal for multi-channel frequency to dc conversion from turbine type flow sensors, tachometers and other frequency output transducers new dc converters achieve linearity of 0.1%. Three outputs are provided simultaneously: 0-5v dc; amplified pulse; and direct reading indicator on front panel. Input frequency range varies from 5 to 3200 cps in 6 overlapping steps which individually adjust over a 2:1 range; input amplitude varies from 5 mv to 100 volts without affecting output. Waugh Engineering Co., Van Nuys, Calif.

Write No. 468 in Box on Inquiry Card

Coax Connector

Instantly engaging or releasing with only a slight movement of the locking device, a quick-disconnect coaxial connector, said to be one of the smallest ever manufactured, measures ¼" x 1⅜" and weighs 5 grams. Captured bayonet locking mechanism is positive acting and will withstand extreme vibration without damage or separation. When mated, the sub-miniature connector will resist a sustained force of over 45 lbs. Nu-Line Industries, Inc., Minneapolis, Minn.

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Claimed to have the only directly coupled in-line readout axailable in 10 megacycle counters, a new unit contains a true decade system which makes binary conversion unnecessary. Use of beam switching tubes results in minimum maintenance and down time. Time base stability of one part in 10^8 per day, count-down time base dividers and self-contained provisions for additional plug-in heads give the units broad capabilities for sophisticated applications. Lavoie Laboratories, Inc., Morganville, N. J.

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Transistor Retaining Clips

Spring clips for socket mounted TO-5 and TO-9 series transistors comply with military requirements for retention of plug-in devices. The clips provide a positive spring pressure retention on the transistor case top and easy access for service. Mounting is accomplished by means of the screw or rivet which attaches the transistor socket to the chassis. A locking tab on the clip positions it and prevents twisting. Mounting height dimensions of 13/64-in. and 21/64-in. are available. Material is beryllium copper per QQ-C-533 with a silver plate finish.. The Birtcher Corp., Monterey Park, Calif.

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Switching Transistor

Incorporating their avalanche mode silicon transistor in a microwave strip transmission line, Raytheon engineers demonstrated a switch that turns off or on in less than one millimicrosecond. The switch, utilizing a reflection technique, produces a clean rectangular pulse. Immediate applications include pulse generators and other instrumentation circuitry. Raytheon Co., Waltham, Mass.

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ROTARY SNAP SWITCH type P

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Weymouth (Boston 88), Massachusetts

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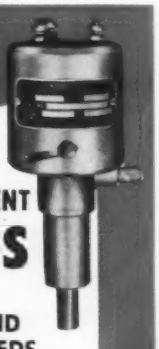
1 to 6 ELEMENT
SWITCHES



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CIRCLE NO. 46 ON INQUIRY CARD

NEW COMPONENTS

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Four thermoelectric generators, in ratings of 5, 10, 50 and 100 watts, are typical of the range of devices that can be produced to special order. Units are completely static and are ideally suited for applications in remote locations. Uses include valve control and powering microwave relay equipment in industrial applications. Units can be designed to combine the use of any type of fuel and any type of cooling medium. Gasoline, propane or natural gas are typical fuels, while forced air, water, or natural convection could be used for cooling. Depending on the application and the type of fuel used, the generators operate at core temperatures between 300° and 600°C. All electrical contacts between pellets are either soldered or brazed; the units are free from pressure bonded contacts which are subject to oxidation and deterioration of subsequent generator performance. The generators basically have low voltage, high current dc outputs. However, a variety of static inverters or converters can be supplied to provide a dc or ac output rating. Westinghouse Electric Corp., Pittsburgh, Pa.

Write No. 372 in Box on Inquiry Card

Sub-Miniature Circuit Breaker

About the size of a matchbox, and weighing only 1½ oz. a hydraulic-magnetic circuit breaker is said to be the first of this type to be priced for commercial applications. It is a commercial version of a military model. The breaker incorporates shock and vibration-resistant features that make it suitable for use in airborne, portable and mobile equipment. Heinemann Electric Co., Trenton, N.J.

Write No. 302 in Box on Inquiry Card

Sequencing Switch

Designed to exceed 50,000 cycles min, a versatile, hermetically sealed, sequencing switch is compact, light, accurate and sensitive. Units meet or exceed Mil-E-527, Mil-I-6181, Mil-5026, and Mil-S-901. They serve wherever rotary motion must be transmitted to circuit control. The operation shaft has a male serrated shaft with female section to accept male section for ganging in multiple sequencing. They can be mounted by bolts or studs with torques up to 40 in-lbs without causing distortion or malfunction of switch mechanism. Acme Machine Works, Hawthorne, Calif.

Write No. 365 in Box on Inquiry Card

Phase Shifting Transducers

Designed with a size 15 synchro mounting, transducers provide a wide range of critically accurate measuring and indicating functions when used at high frequencies. Units generate continuous time delays or phase variations directly proportional to shaft rotation. Furnished as a complete phase-shifting system, the units are said to obtain greater accuracy, stability, and operating speeds than conventional resolvers. Function as a generator, frequency changer or multiple wave phase-shifter, and in frequency response testing of feedback control systems. Nilsen Mfg. Co., Haines City, Fla.

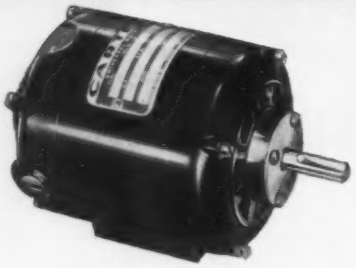
Write No. 304 in Box on Inquiry Card

Variable Speed Drive

Providing infinitely variable output speeds in each of four different transmission ratios, a speed drive obtains every rpm between 180 and 1800 when utilized with an 1800 rpm motor; between 120 and 1200 with a 1200 rpm motor. The four speed transmission is said to result in three times greater torque at the low speed than in any comparable friction type unit. Lima Elec. Motor Co., Inc., Lima, Ohio.

Write No. 397 in Box on Inquiry Card

WANT BETTER MOTORS FOR YOUR PRODUCTS?



20 STANDARD SHUNT AND SERIES MODELS

1/35 to 1/10 hp.

Then switch to Carter Classic

Interchangeable with competitive types. Exclusive performance features include longer brush life, instrument quality ball bearings in steel sleeved housings, highest quality die-cast construction.

Carter also offers a line of 45 miniature Motors and gearmotors 1/1000 to 1/10 hp.

6 to 220v. Series Models . .
6 to 115v. DC Shunt Models

As your specialty motor source, there are no restrictions on modifications, no long delivery, no minimum orders . . . just friendly, personal attention to your requirements.

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BODINE MOTORS
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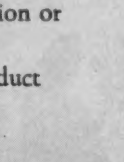
After Delivery Economies

Your end-costs are lower because:

- Bodine Motors perform consistently, never require field servicing . . . (well, almost never!)
- Bodine Motors are easy to fit-in . . easy to adjust.
- You seldom encounter inspection or test rejects.
- Bodine Motors help your product earn repeat sales.

Ask for Bulletin S-2

BODINE fractional / horsepower MOTORS



Bodine Electric Company
2530 West Bradley Place, Chicago 18, Illinois

CIRCLE NO. 48 ON INQUIRY CARD

Transistor Heat Dissipator

Staggered arrangement of the vertical portions of a heat dissipator for power transistors provides positive cooling by radiation and convection. The displaced vertical "pickets", in a forced-air application, provide more air passageways and induced turbulence for increased efficiency and rapid carry-off of heat. The amount of power dissipated by a typical power transistor mounted to a printed circuit board in still air can be increased from 3 watts to 7 or 8 watts Dissipation may be increased to 30 watts by placing the transistor in a forced-air movement. International Electronic Research Corp., Burbank, Calif.

Write No. 301 in Box on Inquiry Card

Heat Exchanger

All aluminum dip-brazed heat exchanger with matching Rotron Muffin fan offers high heat removal at a fraction of the space ordinarily required. Arrangement of internal fins boosts the heat transfer rate by 50% over the non-inner finned type. With fluid temperatures in in the range of 80°C, the unit dissipates approximately 1000 watts of heat. Lytron, Inc., Cambridge, Mass.

Write No. 362 in Box on Inquiry Card

Digital Components

Geometrically identical, digital computer modules measure 0.35 cu in and have a frequency response of dc to 10 Mc. They weigh 7.6 gms and operate over a temperature range —55 to +55°C. A standard 7-pin base design permits easy insertion for prototype work and programming. Both and/or gate and or/and gate designs are included. Cambridge Thermionic Corp., Cambridge, Mass.

Write No. 549 in Box on Inquiry Card

Thin Stable Capacitors

Ultra-thin shape of mylar-epoxy dipped capacitors enables them to fit into narrow chassis spaces. Units especially suit printed circuit and transistor applications. A typical 0.01 mfd. unit measures 0.525" wide and 0.225" thick. At 85°C, capacitance change of only 1.5% occurs. Units operate from —55 to +100°C without derating; to +125°C with 50% voltage derating. Power factor: less than 1% at 1 kc and 25°C. Insulation resistance: 75,000 megohms minimum at 100 vdc, 25°C, 2 min. Capacitances available: 0.01 to 0.33 mfd. Hopkins Engineering Co., San Fernando, Calif.

Write No. 526 in Box on Inquiry Card

Ratchet-Free Stepper Motors

Thin, quit stepper motor operates on low voltage and eliminates mechanical ratchets, electrical contacts or commutators. Having low radiated magnetic fields and high accuracy, it operates with windings continuously energized in static condition or pulsed at rates up to 2400 steps per minute. When one coil is energized in the motor, the rotor advances 15° when the switch is transferred to the next position, energizing the second coil. Returning switch to the first position again energizes the first coil advancing the rotor another 15° and completing one pulse cycle. Thus both coils must be alternately energized to obtain rotation; consecutive pulses to one winding, only, does not advance the rotor. A. W. Haydon Co., Waterbury, Conn.

Write No. 321 in Box on Inquiry Card

Hydraulic Transmission

Continuous duty 10 hp hydraulic transmission provides infinitely variable smooth and constant speeds from 0 to 1600 rpm. Precise speed selected by rotating calibrated hand wheel or by remote control. Ball and roller bearings equipped throughout. Roberts Electric Co., Chicago. Ill.

Write No. 421 in Box on Inquiry Card

"Dyflon"®
Self-Aligning
and
Self-Lubricating
SPHERICAL BEARINGS

Combine "Monoball"® Engineering Advantages with Life-Time Lubrication

Design engineers in many industries are specifying new "DYFLON"® SELF-ALIGNING and SELF-LUBRICATING SPHERICAL BEARINGS for these 5 major reasons:

1. LOWER COEFFICIENT OF FRICTION
...ideal where lubrication is impossible or undesirable.

2. WITHSTAND EXTREME VIBRATION
...perfect performance under shock load conditions.

3. WILL NOT "COLD-FLOW"
...even under extreme load conditions.

4. IMPERVIOUS TO KNOWN CHEMICAL SOLVENTS
...eliminates corrosion problems.

5. FAIL-SAFE ...due to "Monoball"® design.

Request Engineering manual No. 551.

In addition, due to their two-piece "MONOBALL"® design and plastic alloy insert, "DYFLON"® bearings have a long cycle life. Alignment and installation problems are minimized. Oil-free for life means lowest possible maintenance costs.

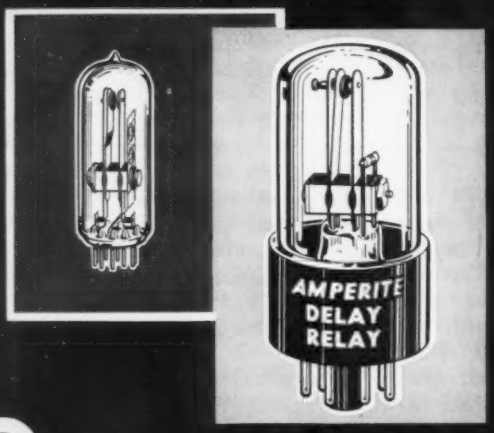
Available in a variety of plain or rod end types. Bore sizes to 3.000". Materials include stainless steel, plastic alloys and chrome alloy steels. Ultimate static loads to 500,000 lbs.

SOUTHWEST PRODUCTS CO. 1705 SO. MOUNTAIN AVE. MONROVIA, CALIF. · PHONE: MURRAY 1-9616

CIRCLE NO. 49 ON INQUIRY CARD

AMPERITE

Thermostatic DELAY RELAYS



Only a glass seal offers true hermetic sealing . . assuring maximum stability and life!

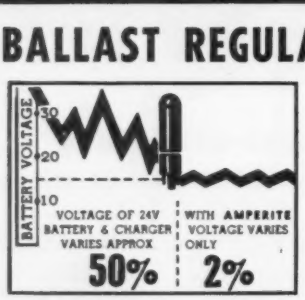
Delays: 2 to 180 seconds . . . Actuated by a heater, they operate on A.C., D.C., or Pulsating Current . . . Being **hermetically sealed,** they are not affected by altitude, moisture, or climate changes . . . **SPST only**—normally open or normally closed . . . Compensated for ambient temperature changes from —55° to +80° C. . . . Heaters consume approximately 2 W. and may be operated continuously . . . The units are **rugged, explosion-proof, long-lived,** and—**inexpensive!**

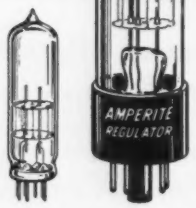
TYPES: Standard Radio Octal, and 9-Pin Miniature . . . **List Price, $4.00.** Also — **Amperite Differential Relays:** Used for automatic overload, under-voltage or under-current protection.

PROBLEM? Send for Bulletin No. TR-81

AMPERITE

BALLAST REGULATORS





Hermetically sealed, they are not affected by changes in altitude, ambient temperature (—50° to +70° C.), or humidity . . . Rugged, light, compact, most inexpensive . . . . . **List Price, $3.00.**

Write for 4-page Technical Bulletin No. AB-51

AMPERITE

561 Broadway, New York 12, N. Y. . . . . CAnal 6-1446

In Canada: Atlas Radio Corp., Ltd., 50 Wingold Ave., Toronto 10

CIRCLE NO. 50 ON INQUIRY CARD

NEW COMPONENTS

Shaft Encoders

Eliminating ambiguity through use of precision detented indexing, Guidance Controls Corp. has developed sizes 20 and 30 analog/digital encoders for translating a rotary shaft position to a coded digital output for tape storage or direct insertion into digital computers. Provisions have also been made for visual read-out of shaft position by means of a dial mounted on the face of the housing with a pointer attached to the encoder shaft. In this manner the detented encoder functions as an end-input positioner for use in automated production lines, process control and other applications. Precision detented indexing provides a guaranteed non-ambiguous output. Since the brushes and code pattern contained on the discs constitute the entire reading circuitry, external electronics (other than input circuitry) are not required. Guidance Controls Corp., Hicksville, N. Y.

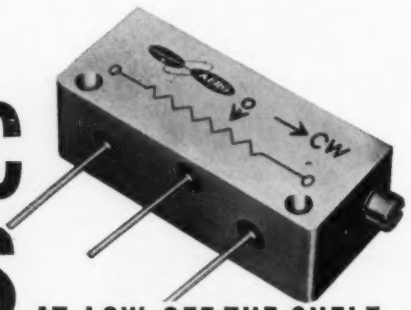
Write No. 305 in Box on Inquiry Card

Size 5 Brakes and Clutches

Patent pending "no-creep" design in size 5 clutches and brakes guarantees no angular displacement. In addition, the use of new materials eliminates loss of torque during life; in fact, torque tend to increase. The new units will exhibit no torque variation with fluctuating temperature up to 125°C. Torques at 28 volts dc excitation for the clutches are: engaged (minimum) 6.0 oz-in, disengaged (maximum) 0.05 oz-in. Brake torque (minimum) is 2.0 oz-in. Clifton Precision Prods. Co., Drexel Hill, Pa.

Write No. 308 in Box on Inquiry Card

MIL SPEC POTS



AT LOW OFF-THE-SHELF PRICES—FROM AERO ELECTRONICS

- *Aeropots meet all applicable requirements of MIL-R-27208A.*
- *Reliable performance guaranteed for well over 1,000 hours.*
- *All welded internal connections.*
- *Terminals gold plated for easy soldering.*
- *Available for printed circuit, standard and panel mounting.*

Aeropots are the best buy in quality trimming potentiometers.

Write for technical data and brochure on the complete line of advanced design Aeropots.

AERO ELECTRONICS CORPORATION

1739 W. 134th Street • Gardena, Calif.

CIRCLE NO. 57 ON INQUIRY CARD

Control Knobs

Specially-designed slide sule and wall chart provide a finger-tip selection of more than 345 styles of control knobs. With the slide rule, you can pin-point the exact knob for your particular needs simply by setting the required specs on the sliding panel and then picking any one of the desired styles, indicated by the rule, that satisfy the specs. Permanent wall chart offers the same data as the selector plus dimensional pictures of each style knob. All control knobs meet mil specs.

Source: Raytheon Co.
Lexington, Mass.
For Your Copy: Write No. 800 in Box on Inquiry Card

Torque-Tension in Fastening

Twelve tables listing specific recommended installation torque values for thin and standard height hex type lock nuts are included in an 18 page design manual. It discusses factors to be considered in selecting a tightening torque and the effects of the use of lubricants. Additional data includes tables of tensile stress areas and bolt strengths.

Source: Elastic Stop Nut Corp. of America
Union N. J.
For Your Copy: Write No. 801 in Box on Inquiry Card

Rate and Acceleration Nomograph

Particularly useful for working with rate gyros and angular accelerometers, a nomograph aids in the rapid determination of rate and acceleration when the frequency and the displacement are known.

Source: Micro Gee Products, Inc.
Culver City, Calif.
For Your Copy: Write No. 802 in Box on Inquiry Card

Measuring Rotating Power

How to measure the torque characteristics and speed of motors, gear trains, servomechanisms and potentiometers is answered in a brochure covering instruments involved with these measurements. Torque ranges from ¼ gm-cm to 200 lb-in. are discussed. Also included are formulas for computing power and efficiency, and methods of using stroboscopes and tachometers for analyzing rotating motion.

Source: Power Iinstruments, Inc.
Skokie, Ill.
For Your Copy: Write No. 805 in Box on Inquiry Card

Terminal Insulators

24-page bulletin includes a description of the insulator ceramic, forming techniques used, high temperature metalizing and brazing techniques and inspection. A section is also devoted to special metalized assemblies. 4-page section, "How Ceramic-to-Metal Seals are Made," gives data for designing special ceramic and metal assemblies.

Source: Coors Porcelain Co.
Denver, Colorado
For Your Copy: Write No. 807 in Box on Inquiry Card

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ACTUAL SIZE

Get "Giant Size" Readability In a "Pint Size" Package

SPECIFY Bowmar ELAPSED TIME INDICATOR MODEL 1440

- DIGITAL READOUT to 9999 hours in one hour increments
- SUBMINIATURE - Only .670 OD; 1.670 L
- FEATHERWEIGHT - Less than 2 ounces
- 115 V 400CPS OPERATION
- MINIMUM POWER DRAIN
- HERMETICALLY SEALED
- MOUNTS TO ANY PANEL THICKNESS
- MEETS REQUIREMENTS OF Mil-M-26550

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BOWMAR INSTRUMENT CORPORATION
8000 Bluffton Rd., Fort Wayne, Ind.
FOR CONTROL OF THE FUTURE
CIRCLE NO. 51 ON INQUIRY CARD

WORTH FILING

Zener Diode

Four-page bulletin covers zenor diode theory, characteristics and applications. Typical circuits using zener diodes are shown for: the shunt regulation of both ac and dc voltages, the voltage reference element in a transistor-controlled regulated power supply, the cathode resistor in vacuum tube amplifiers, the regulation of vacuum tube heaters, and the suppressed zero voltmeter with expanded scale. Advice on the use of zener diodes in series, as well as in parallel, is included.

Source: CBS Electronics
Danvers, Mass.

For your copy: Write No. 829 on Inquiry Card

DC Power Supplies

Catalog of more than 80 models of semiconductor dc power supplies gives detailed performance characteristics in current ratings to 100 amperes including wide-range, narrow range, and compact half-rack models. There is a concise explanation of the programmability feature. Catalog offers sufficient data to permit incorporation of a dc power supply into systems directly from its pages.

Source: Electronic Measurements Company,
Red Bank, Eatontown, N. J.

For Your Copy: Write No. 813 on Inquiry Card

Rolling Diaphragms

Containing 26 pages covering description, operation, advantages and other design data on "friction free" rolling diaphragms, a design manual also includes a nomograph for fast figuring of maximum up or down strokes in piston applications.

Source: Bellofram Corporation
Burlington, Mass.

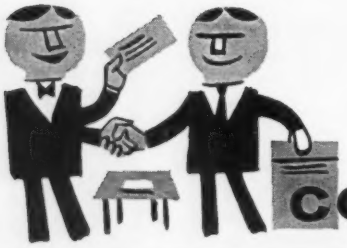
For your copy: Write No. 815 on Inquiry Card

Power Supply Catalog

Detailing over 200 power supplies plus 1,000,000 combinations of kitted modules, 24-page manual includes a step by step procedure for calculating packaging dimensions for multiple dc outputs. Considered are spacing problems for modular dc power supplies under various conditions of ambient temperature, external cooling and rated current.

Source: Dressen-Barnes Electronics Corp.
Pasadena, Calif.

For your copy: Write No. 811 on Inquiry Card



CONTRACTS

Cross a digital computer with an analog computer and what do you get? Well, that's the key to the performance of Computer Systems' 5800 Dystac Interative Analog Computer. The analog's speed, lower cost, ease of programming and improved output data presentation are combined with the digital computer's unique capacity for data storage and time sharing of components. Four of these computers are to be installed at the David Taylor Model Basin under a $296,000 contract. According to William Ogletree, Computer Systems vice president, the installation will provide rapid, accurate answers to the wide range of complex problems encountered in the design, stability and control of advanced vessels. Dystac computers will be used to simulate or model physical systems electronically. Equipment can then be studied and operating characteristics determined without constructing costly prototypes or performing long trial-and-error operations. The computer "model" can be rebuilt in minutes and tested hundreds of times thus saving costly engineering or construction time. High speed repetitive capabilities are combined with dynamic storage of analog data to an accuracy of 0.01 percent and a time base accuracy of 0.5 microsecond.

"The forget-me-nots of the angels" are in for a closer view. The Orbiting Astronomical Observatory (OAO) Project, according to NASA scientists, will provide the greatest advance in astronomy since the development of the 200 inch reflective telescope at the Mount Palomar Observatory. For the first time in history, man will be able to get beyond the earth's atmosphere to study radiation from celestial sources. The orbiting observatory will be used primarily to measure ultraviolet radiation from an extraterrestrial source. Each of the satellites is expected to be operational for approximately one year. Under an initial contract, amounting to slightly over $1 million, Kollsman Instr. Corp. will develop and manufacture six star trackers for each of the three space vehicles presently planned, plus the associated electronic equipment. The company will also make the test equipment required to check out the star trackers before launching. The goal of the OAO Project is to provide scientists with data on stars and planets presently unavailable due to the effects of the earth's atmosphere. The one and one-half ton space craft is being built by Grumman Aircraft Engineering Corp. under a $23 million contract with the NASA. The first space craft is scheduled for launching in 1963-1964.

Research on new methods of encapsulating semiconductor devices will be conducted by Motorola's Semiconductor Prods. Div. under an Air Force contract totaling $841,500. Motorola will study manufacturing refinement methods and applications of advanced surface passivation techniques as applied to silicon diodes and silicon mesa transistors. Units will be packaged in recently-developed glass materials which completely seal the active region from the outside contaminants thus eliminating the need for bulky packages now used. Test devices will be subjected to extended reliability verification testing and will be evaluated against control samples of similar standard devices now manufactured by Motorola. Preliminary tests conducted on glass encapsulation processes indicate an order of magnitude improvement in electrical parameters and in reliability.

BRIEFLY:

Long range radars: $36,000,000 to G. E.'s HMED, Syracuse, N. Y. from the Navy.

Navigational computers: Over $750,000 to Huyck Systems Co., Huntington, L. I., N. Y. from Lockheed Airc. Co.

Electrical connectors: $900,000 to Scintilla Div. of Bendix, Sidney, N. Y. for Polaris.

Servo amplifiers: $571,200 to Electronics Div. of Bulova Watch from Holland.

Frequency shift converters: $2.3 million to Hoffman Electronics, L. A., Calif. from the Navy.

Infrared detection: $3 million to Baird-Atomic, Inc., Cambridge, Mass. for Midas.

For Your Literature File

NEW CATALOGS

Most of these catalogs contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the catalogs listed on this page, enter the appropriate number of the item on the Inquiry Card.

Laminated Plastics 952

First two pages of catalog describe laminated plastics and vulcanized fibre in general terms, telling how they are made and where they can be used, pointing out that more than 50 grades of laminated plastics are available to meet any requirement. Two 2-page tables lists the properties and grades of the plastics and fibres. (8 pp) Taylor Fibre Co., Norristown, Pa.

Rotary Switches 967

Selection chart and a tabulation of parameters in brochure are a great aid in choosing a high speed rotary switch for telemetering, programming, commutating, sampling, multiplexing or a computing application. (6 pp) Instrument Development Laboratories, Inc., Attleboro, Mass.

Switches 655

Description of the applications, materials and characteristics of a line of switches is followed by a section instructing the user on a "shorthand" method of ordering switches of various operating characteristics. Some of the standard switches listed include: single deck, shorting; single deck, non-shorting; multiple deck, shorting; multiple deck, non-shorting; as well as special switches like miniature ceramic switches, sub-miniature switches, prewired switch assemblies and many more. (48 pp). Daven Co., Livingston, N. J.

Ball Bearings 653

Self-aligning bearings and rod end bearings described in detail in a catalog which covers an entire line. Included is a new series of "Dyflon" plastic alloy insert, self-lubricated bearings which are available in a variety of plain or rod end types. Bore sizes are now offered up to 6.000". Ultimate static loads up to 4,500,000 lbs. Materials include stainless steel, plastic alloys and chrome alloy steels. (56 pp). Southwest Products Co., Monrovia, Calif.

Power Springs 988

Flat spiral springs and variations of a new spring design include: spiral, crosscurved, stainless and integral band types with and without bridle. Applications and specific examples of spring problems which have been solved are discussed. Booklet also includes reference data on spring nomenclature and types of ends and centers and lists data required when ordering. (12 pp) Sandvik Steel, Inc., Fair Lawn, N. J.

Venturi Valves 658

The solenoid piloted, remotely actuated version of the valves discussed is devoid of any dynamic seals or packing such as o-rings, bellows, etc. Leakage to the outside ambient, short of osmosis, cannot occur. Inasmuch as line pressure itself is used to power the valve open or closed, external actuators employing auxiliary hydraulic or pneumatic power are not required. A manually operated version of this valve, recently developed, operates by finger flicking a toggle type lever, *regardless of valve size or pressure in the line.* Included in a pamphlet is a chart on the characteristics of venturies. This chart applies not only to conventional flow through a venturi section but encompasses the cavitation regime of liquids, cryogenic or conventional. Data given such as experimentally determined discharge coefficients and diffuser recovery efficiencies allows you to design your own cavitating venturi and establish flow versus pressure drop characteristics. Fox Valve Development Co., Inc., Verona, N. J.

Magnetic Devices 951

Miniature toroidal transformers, inductors, magnetic amplifiers and other magnetic devices are fully described. Encapsulated and hermetically sealed, units meet MIL-E-5272 and MIL-T-27A. Circuit diagrams and typical curves are among the data given. (20 pp). Arnold Magnetics Corp., Los Angeles, Calif.

Temp Regulating Devices 676

Temperature regulating devices routinely control air or liquid temperatures within a fraction of a degree. Catalog treats bimetal and mercury thermoregulators, heaters, relays, stirrers, pumps, and transformers. Devices operate in any type container from a mason jar to a lab bath to an entire room. American Instrument Co., Inc., Silver Spring, Md.

Servo Motors 969

Bulletin describing two phase, four pole reversible induction motors, contains three sets of speed-torque curves. One shows typical performance for four different stator stackings when both windings are connected to a 115 v line. Second shows typical performance for four different stator stackings with 115 v on the fixed winding and 200 v on the control winding. Third shows typical performance of a motor with 0.7 in. of stator stacking, with 115 volts on the fixed winding and 50, 100 and 200 volts on the control winding. Also given are other pertinent motor data. (4 pp) Holtzer-Cabot Motor Div., National Pneumatic Co., Inc., Boston, Mass.

Electromagnetic Relays 673

With most of the information presented in charts for ready comparison between relays, a catalog describes 42 different relay series. They have been divided into 4 major groups: telephone type, military, power and general purpose. Literature also gives mounting data, descriptions of numerous enclosures and information on terminals. (16 pp) Potter & Brumfield, Princeton, Ind.

Variable Phase Standard 675

With at least $\pm 0.05°$ accuracy, a variable phase standard shifts phase between 2 self-generated voltages to any angle. It operates at any of three fixed frequencies within 150 to 3000 cps. Unit's output voltage measures 50v rms (reference), 0-50v rms (vector). Vector output attenuates in steps of 50 mv. Brochure includes a simplified block diagram. (4 pp) Gertsch Products, Inc., L. A., Calif.

Limit Switch 973

Without physical contact, a new magnet-operated limit switch accurately detects the position of objects moving in erratic paths. Text explains that no arms, levers, rods, shafts or slots are necessary with the switch which is actuated by passage of a permanent magnet near the switch face. (4 pp) General Electric, Schenectady, N. Y.

Thermocouple Selectro Switches 972

Multi-point switches have temperature checking applications, such as: when temperature being sensed by a number of thermocouples must be checked frequently or switched from on instrument to another; when several temperature readings are to be averaged; and when measuring instruments have to be switched to different measuring points. Described in detail are: a rotary switch with 6, 12, or 24 point capacity; key switches for up to 144 points; and push-button models for up to 72 point operation. (4 pp) Fred Lange Assocs., N. Y., N. Y.

Miniature Logic Circuits 974

Fully encapsulated for complete environmental protection and reliability, more than 20 basic AND gates, OR gates, emitter followers and inverters are designed for self-compatibility and compatibility with other off-the-shelf modules. Miniature plug-in units, in the versatile 9 pin form are avaialble, also diminutive type "CM" cartridge configuration, popular with airborne and space users. Walkirt Co., Inglewood, Calif.

Fans and Blowers 993

Special section of catalog covers basic design information for ventilating electronic equipment using forced-air cooling. Mathematical formulae and graphs are provided for solving specific problems in the cooling of either solid state electronic circuitry or vacuum tube assemblies. Performance curves and characteristics of packaged blowers, propeller fans, single and dual centrifugal blowers, and ring fans as well as data on special cooling equipment are included. (48 pp.) McLean Engineering Laboratories. Princeton, N. J.

POTENTIO-METERS

RELIABILITY

DIGITO-METERS

ROTARY SWITCHES

by

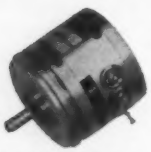
ELECTRO-MEC

All our instruments offer you design flexibility and long life.

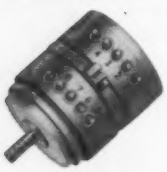
Step up reliability.

Step down size of your system.

POTENTIOMETERS: A complete line of superprecision linear and non-linear potentiometers. Certified calibration data, including recordings of output function are supplied with each instrument. All AIA sizes from RR-09 to RR-30.



DIGITOMETERS: Four sizes are available in this shaft angle digitalizer, 1.06" to 3.00" Dia. When you operate under severe ambient conditions, always specify Electro-Mec Digitometers. They are designed to withstand the rigors of MIL (E) 5272 environmental tests.



ROTARY SWITCHES: Our newest product with the same built-in reliability you have come to expect from Electro-Mec. .875" to 3.00" Dia., these Rotary Switches can be supplied singly or in combination with potentiometers. Current capacity up to 250 ma.

For further information or for data sheets, write or telephone our Engineering Department.

ST-6-3402 Teletype: NY-4-2126

ELECTRO-MEC DIVISION OF WALTHAM PRECISION INSTRUMENT COMPANY, INC.

47-51 33 Street — Long Island City 1, N.Y.

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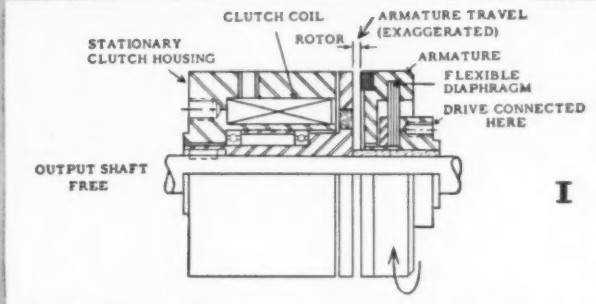
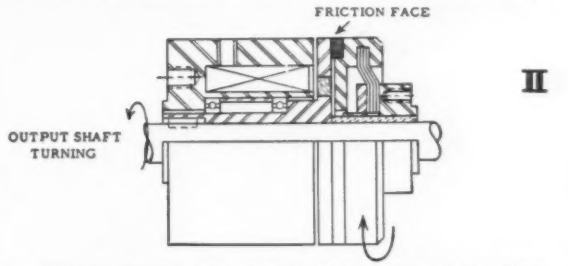
Choose A Diaphragm Electric Clutch

for Superior Performance Lower Installed Cost



I. DE-ENERGIZED: Armature turning, shaft stationary



II. ENERGIZED: Output shaft being turned by drive through armature to rotor

Like most really sound engineering ideas the practicality and economy of electric clutches and brakes without the conventional sliding armature had to be proved in practice.

Now, a few short years after their introduction, Simplatrol electric clutches and brakes **have** proved that their design, based on a flexible diaphragm in the clutch's armature, does do a better job than armature plates sliding on splines, pins, or hubs.

Simplatrol's armature, a **one-piece** assembly, deflects to perform clutching or braking action. Wear is reduced to vanishing point since there are no sliding parts to contact each other; instant performance is achieved without slow release, or "hanging up."

This Simplatrol diaphragm principle ensures smoothness, quietness, and consistency.

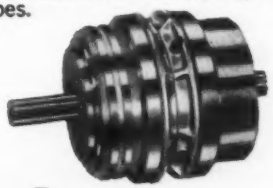
Compare the installed cost.

Simplicity carries through to the installation, reducing cost here as well. You simply slip one of the 2 or 3 major assemblies onto the shaft — that's all the assembling you do! No pins, no nuts, no washers, no springs to run up labor cost.

Machined parts in the clutches and brakes are of uniform quality. There's close built-in control of tolerances and finishes . . . and the assemblies are pre-burnished! All clutches include bearings, machined surfaces and bolt holes for direct mounting of your drive unit.

Simplatrol offers a complete range of diaphragm electric clutches from torque of 10 ounce inches to 470 pound feet in diameters from ⅞" to 12½". Styles include clutches, brakes, clutch-brakes, duplex clutches, and couplings in both rotary and fixed field types.

Ask Simplatrol's sales engineers to demonstrate to you specifically how the unique advantages of flexible diaphragm performance will benefit your operation.



Simplatrol products corp.

24-9 SALISBURY ST., WORCESTER, MASS.

Representation in Key Industrial Areas

339-0

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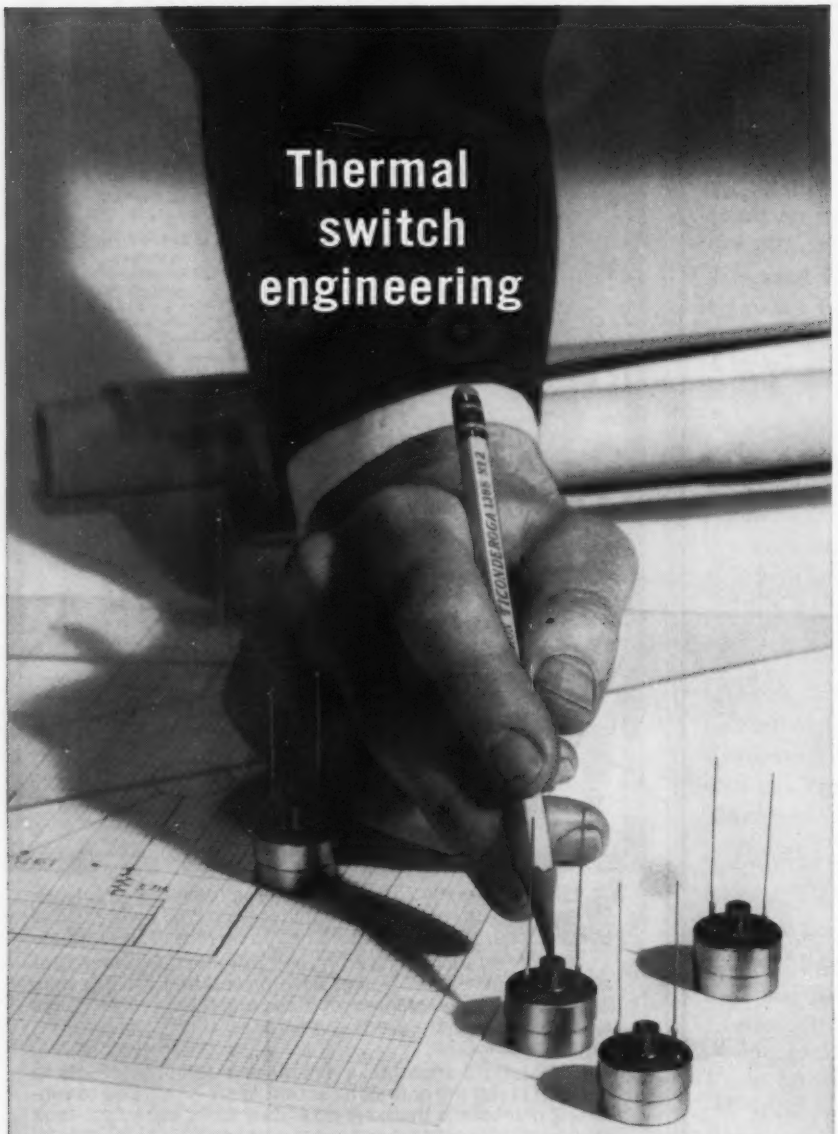

ANOTHER "CRITICAL" CONTROL SWITCH FROM CPI RESEARCH

If you are concerned with measurement of surface temperatures in aircraft and airborne electronic equipment in confined spaces, this may be a thermal switch you could use. We designed and manufactured it to meet exacting specifications of a prominent aircraft manufacturer.

Chances are your needs may require modifications or even a completely new switch. We have always realized that there are few "critical" control switches that can be all things to all people. That's why we have the research and development engineers who can and do tackle specific problems of thermal control. Can we help you solve yours?

This new hermetically sealed, bi-metal, single or 2-wire switch has calibration range of -20F to 600F; safe momentary overshoot to 800F; available with various type mountings. When inquiring, mention "button" switch.

CONTROL PRODUCTS, INC.

272 Ridgedale Avenue, Hanover, N.J.

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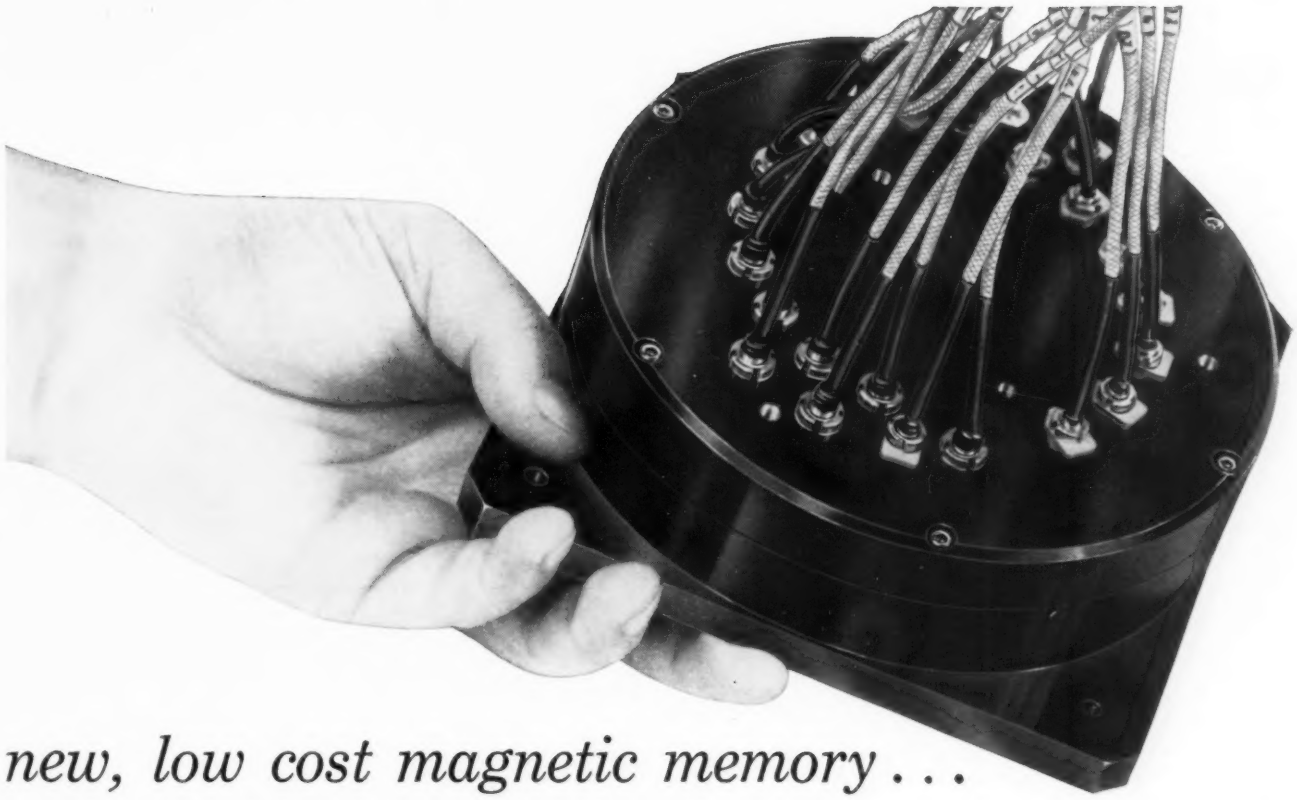


new, low cost magnetic memory . . . 25,000 bit capacity . . . 5¾" x 5¾" x 5" . . . 5 pounds

The BD-10 Series is the latest addition to LFE's expanding line of Bernoulli Disk Memory Systems. It has been designed to fill the need for a low capacity, low cost storage device. It is available in single units for laboratory use, or in high volume production for use with all digital computers utilizing magnetic storage media.

A flexible Mylar magnetic disk, headplate, read/write heads and a precision motor are the basic components. Positive separation between disk and headplate is maintained by centrifugal force and the Bernoulli principle of fluid motion. The unit's low mass plus a cushion of air make damage to disk or read/write heads virtually impossible . . . even under the most severe environmental conditions. Write Marketing Manager, Computer Products Division, for prices and complete data.

SPECIFICATIONS BD-10 SERIES

Storage Capacity (max.) Bits	25,000
Disk Diameter (max.) Inches	4
Bits per Track (max.) @ 1½" radius	2,300
Bit Rate — kc	10-500
Track Layout As Required	
Typical:	
Total Tracks:	12
Data Storage Tracks	*
Spare Tracks	*
Clock and Timing Tracks	*
Register Tracks	*
Number of Registers	*
Register Length — Bits (minimum @ 2,300 B/T)	32
Register Adjustment — Bits	±3
Disk Speed — RPM Induction or Synchronous Motors Available	6,000-12,000
Power Source — cps	400
Magnetic Heads (Compatible with solid state circuits)	
Standard Heads	
Inductance (Per Leg. — C.T. Coil) uh	40, 55, 90
Write Current (O/P Manchester) ma (nominal)	125
Read Out (Min. P/P Full Coil) — mv (nominal)	20
Size — Inches	5¾ x 5¾ x 5
Weight — Pounds	5

*Wide variety of specifications can be provided to meet customer's requirements.

LFE
COMPUTER PRODUCTS DIVISION

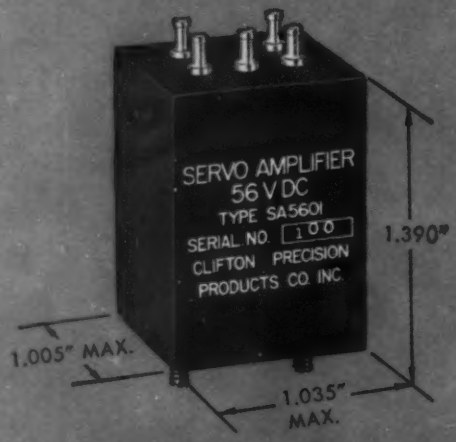
LABORATORY FOR ELECTRONICS, INC.

1079 COMMONWEALTH AVE. • BOSTON 15, MASSACHUSETTS

CIRCLE NO. 56 ON INQUIRY CARD

High Fidelity in SERVO Amplifiers?

ACTUAL SIZE



VOLUME = 1⅞ CUBIC INCHES

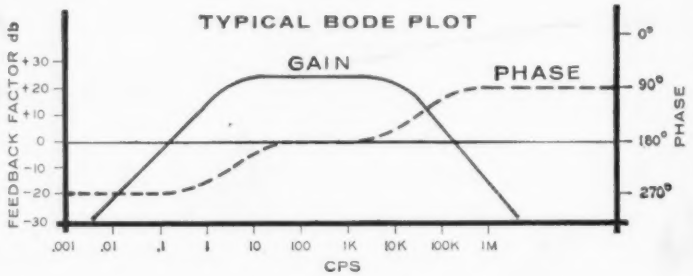
YES! Look at these specifications

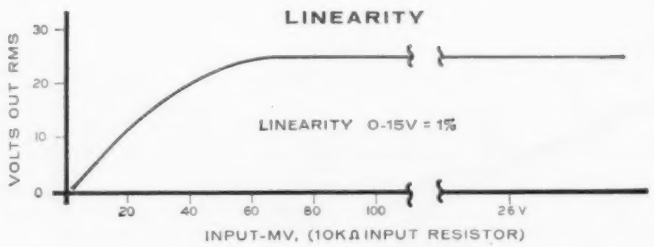
POWER OUTPUT 5W
± 3 db 10 cps – 30 kc
< 1% THD AT 2 WATTS
FEEDBACK > 20 db
GAIN MARGIN > 20 db
PHASE MARGIN > 90°
TEMP. RANGE −55 +125°C
EFFICIENCY > 65%

CPPC's new 5 watt servo amplifier provides a unique combination of exceptional stability and miniature size. Built around a DC amplifier with high frequency cutoff above 30 kcps, the SA 5601 provides uniform response over its full operating range. With a 10 kΩ input resistor the SA 5601 yields a voltage gain of 54 ± 1 db from −55° to + 125°C with all signal levels below saturation, and supply voltage of 56 ± 3 volts. Idling power is under 1 watt.

Designed to drive any size 8, 10 or 11 servo motor with a 26 volt control-phase rating, the SA 5601 is available off the shelf with stud or screw mounting. A regulated supply of the 56 VDC power required for the SA 5601 operating from 115 V 400 ~ and providing a 26 V AC tap for motor and synchro excitation is available in a similar package.

For information phone or write: Area 215 MAdison 2-1000, TWX LNSDWN, Pa. 1122(U) – or our Representatives.





CLIFTON PRECISION PRODUCTS CO., INC.
Clifton Heights, Pennsylvania
CIRCLE NO. 55 ON INQUIRY CARD

cppc SYSTEMS DIVISION